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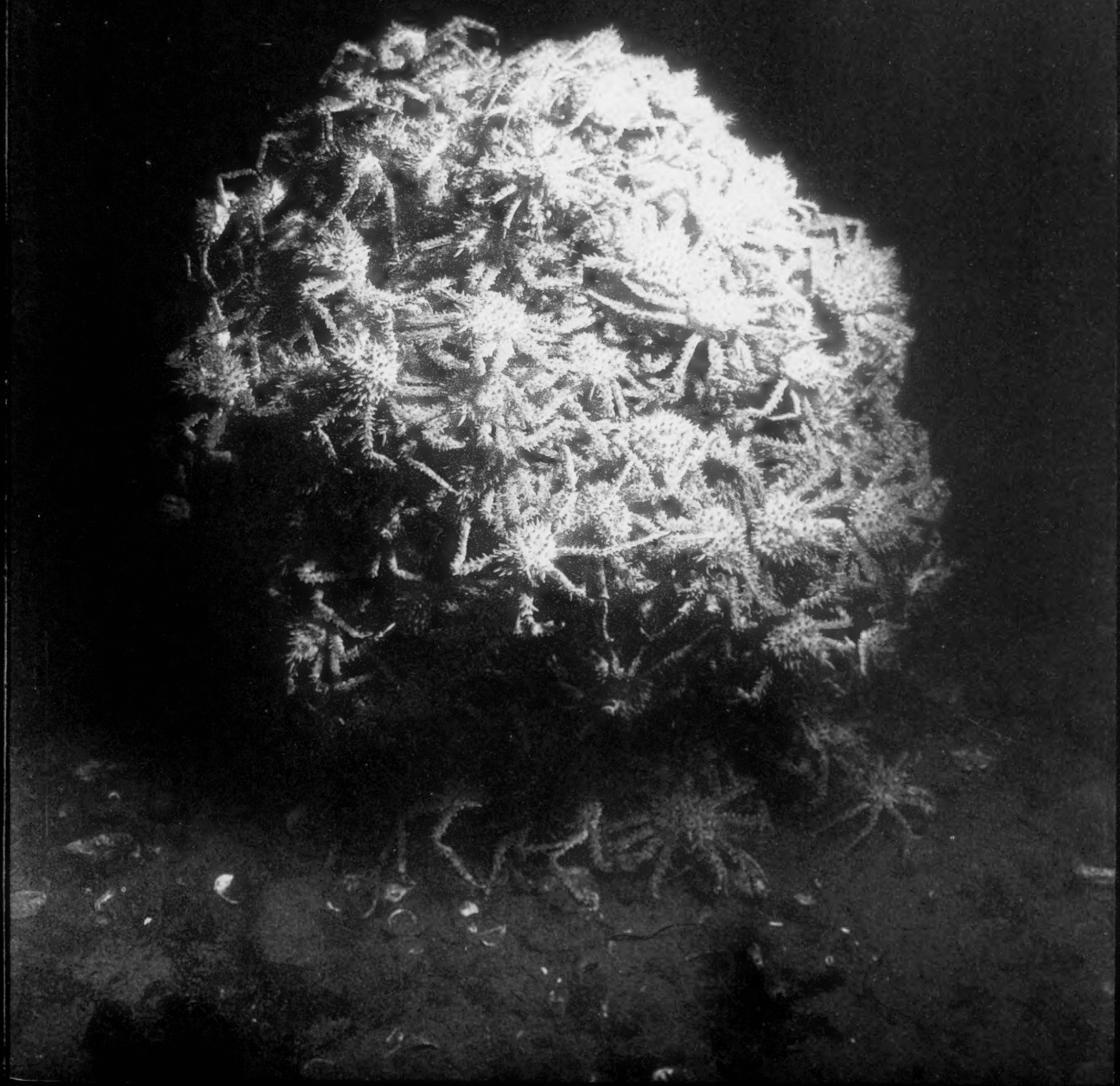

Marine Fisheries REVIEW

W. L. Hobart, Editor
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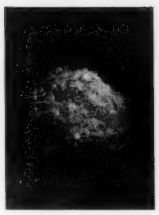
On the cover:
A daytime resting pod of age-1 red king crab, each about the size of a 50-cent piece, at Kodiak, Alaska. Each evening, these juveniles disperse from the resting pod, forage as a cohesive unit throughout the night, then reconstitute the resting pod in the morning. As they grow to adulthood, red king crab continue their highly gregarious podding behavior. Although adults spend most of their time in foraging aggregations, adult resting pods 2–3 meters high have been observed and photographed at Kodiak. Photo by Braxton Dew.



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History of Alaska Red King Crab, *Paralithodes camtschaticus*, Bottom Trawl Surveys, 1940–61

MARK ZIMMERMANN, C. BRAXTON DEW, and BEVERLY A. MALLEY

Introduction

The U.S. government was integrally involved with the development of Alaska's red king crab, *Paralithodes camtschaticus*, fishing industry (Blackford, 1979). In 1940 Congress appropriated funds for surveys of Alaska's fishery resources (Schmitt, 1940; FWS, 1942). Based on the U.S. Fish and Wildlife Service's (FWS) exploratory work for red king crab during the 1940's, skeptical commercial trawlers expected the bulk of their profits to come from bottomfish. However, as commercial fishing ventures ramped up after World War II, it was soon apparent that red king crab dominated the epibenthic biomass of the southeastern Bering Sea and would be the major product (Blackford, 1979).

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As early as the 1930's, the Alaska red king crab resource was a heavily exploited species, with significant foreign commercial harvests occurring well before the first U.S. (1940–41) exploratory bottom trawl survey (Schmitt, 1940; FWS, 1942). During the 1930's, Japan and Russia together took 9–14 million kg of king crab per year from the southeast Bering Sea, within the vast area referred to as Bristol Bay.

In 1946, U.S. fishermen began commercial king crab fishing in these same waters, and by 1963 the United States dominated the fishery (Blackford, 1979). By 1960, after trawls and tangle nets were outlawed as capture methods for Alaska king crab, only pots could be fished and only male crabs could be retained, with all females and undersize males being released. Despite these substantial restrictions, during the 1970's, the male-only red king crab fishery was the most valuable single-species fishery in Alaska and, after decades of increasing catches, the all-time record U.S. harvest of 59 million kg of Bristol Bay legal crab (males with a carapace length ≥135 mm) was recorded in 1980. Then, in 1981, the Bristol Bay red king crab population abruptly collapsed in one of the more precipitous declines in the history of U.S. fisheries management. In the opinion of Alaska crab managers and modelers (Otto, 1986; Zheng and Kruse, 2002; NPFMC[1]), the crash of the Bristol Bay red king crab stock was a natural phenomenon unrelated to commercial fishing.

Considering the history of the Bristol Bay red king crab commercial fishery and the unresolved issues surrounding the 1981 collapse (Dew and McConnaughey, 2005), it is possible that data from the 1940–61 surveys might be of some help in answering the question of whether the stock was overfished. An important reference point used to assess the relative health of a stock is the virgin stock biomass (B_0). If the ratio between current and virgin biomass (B/B_0) is below some predetermined threshold, then the stock is diminished to the point where it may be characterized as being overfished. According to Pereyra et al.[2], the baseline year for the Bering Sea bottom trawl program is 1975. However, it is likely that earlier surveys, conducted during the 1940's and 1950's, can tell us more about the B_0 of Bristol Bay red

ABSTRACT—Thirteen bottom trawl surveys conducted in Alaska waters for red king crab, Paralithodes camtschaticus, *during 1940–61 are largely forgotten today even though they helped define our current knowledge of this resource. Government publications on six exploratory surveys (1940–49, 1957) included sample locations and some catch composition data, but these documents are rarely referenced. Only brief summaries of the other seven annual (1955–61) grid-patterned trawl surveys from the eastern Bering Sea were published. Although there have been interruptions in sampling and some changes in the trawl survey methods, a version of this grid-patterned survey continues through the present day, making it one of the oldest bottom-trawl surveys in U.S. waters. Unfortunately, many of the specific findings made during these early efforts have been lost to the research community. Here, we report on the methods, results, and significance of these early surveys, which were collated from published reports and the unpublished original data sheets so that researchers might begin incorporating this information into stock assessments, ecosystem trend analyses, and perhaps even revise the baseline population distribution and abundance estimates.*

[1]NPFMC. 2000. Stock assessment and fishery evaluation (SAFE) report for the king and Tanner crab fisheries of the Bering Sea and Aleutian Islands (BSAI) regions. Crab model structures and model fits. Appendix 1:330–348. Compiled by the plan team for king and Tanner crab fisheries of the BSAI. Unpubl. rep. available from the North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, AK.

[2]Pereyra, W. T, J. E. Reeves, and R. G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., NWAFSC Proc. Rep., 619 p.

king crab than a 1975–80 data series collected from a highly exploited stock on the brink of collapse. Also, according to an Environmental Impact Statement on Essential Fish Habitat, "the abundance of red king crabs in the late 1970's was anomalously high and should not be viewed as a realistic goal for restoring the population" (NMFS, 2005:L-19). However, the accuracy of this statement is difficult to verify without reference to data from surveys during the 1940's, 1950's, and 1960's.

From 1940 through 1961, a series of bottom-trawl surveys was conducted to determine the biology, distribution, and means of commercially exploiting the red king crab population in Alaska waters. The first surveys (1940–49, 1957) were wide-ranging explorations, as well as cooperative arrangements between government research agencies and the private fishing industry, with the intent of identifying crab concentrations and harvest methods needed to create a self-sustaining U.S. red king crab canning industry. The later surveys (1955–61) were conducted on a predetermined grid station pattern in the eastern Bering Sea and run by researchers at the Seattle Biological Laboratory, or "Montlake Lab," to monitor the effect of the red king crab fishery on crab populations. [The parent research agency was termed the Fish and Wildlife Service from 1940 to 1955 and then the USFWS Bureau of Commercial Fisheries (BCF) starting in 1956.] In the early1960's the red king crab program was transferred from Seattle, Wash., to Juneau, Alaska. The program was again moved to Kodiak, Alaska, in 1970 (Greenwood, 1982). The interruptions in the red king crab program might partly explain why these early surveys are never referenced in the reports on current annual crab (e.g. Rugolo et al.[3]) and groundfish bottom trawl surveys (e.g. Acuna and Lauth, 2008), which are conducted jointly by the Alaska Fisheries Science Center's (AFSC) Shellfish Assessment (Kodiak) and Groundfish Assessment (Seattle) Programs, and is a direct descendant of these original trawl surveys. Our objective is to describe the purpose, effort, and findings of the early red king crab bottom trawl surveys so that the information can be utilized today. Besides red king crab data, there is also catch information on other invertebrate and fish species, seafloor substrate types, foreign fishing vessel activity, surface and bottom water temperatures, and bird and marine mammal sightings.

Figure 1.—The halibut schooner *Dorothy*, which participated in the 1940–41 Alaska king crab exploration and in the 1948 *Pacific Explorer* fleet expedition. Its small engine could be supplemented with sail supported by two masts. Bottom trawl gear was set and retrieved over the side. The dories on the stern of the vessel were used by pairs of men for halibut hand-lining. Photo of the *Dorothy* at Mitrofania Island, Alaska, courtesy of the Lokken collection (#212012) at the Museum of History and Industry, Seattle, Wash. Photo credit: Puget Sound Maritime Historical Society.

Exploratory Bottom Trawl Surveys, 1940–49, 1957

Tondeleyo and *Dorothy* (1940) and *Dorothy, Champion*, and *Locks* (1941)

The primary motivation for launching the Alaska red king crab investigations was to determine the information needed (areas of abundance, crab capture methods, and canning techniques) to develop a domestic crab fishing industry, as it was noted that Americans were purchasing millions of pounds of canned Alaska crab meat taken by Japanese and Russian vessels operating in Alaska waters (FWS, 1942). The first red king crab exploration was undertaken in the fall of 1940 aboard the *Tondeleyo* and *Dorothy* (Fig. 1) (Schmitt, 1940), and it was completed aboard the *Dorothy*, *Champion,* and *Locks* in 1941 (FWS, 1942). These were private vessels chartered by the eight staff members of the Alaska Crab Investigation Staff of the Fishery Technical Laboratory in Seattle (Montlake) with money provided by Congress (FWS, 1942). This survey was the most extensive in terms of geographic area covered, seasons fished, gear experi-

[3]Rugolo, L. J., E. A. Chilton, C. E. Armistead, and J. A. Haaga. 2006. Report to industry on the 2006 eastern Bering Sea crab survey. AFSC Proc. Rep. 2006-17, 61 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., Kodiak Fish. Res. Cent., Kodiak

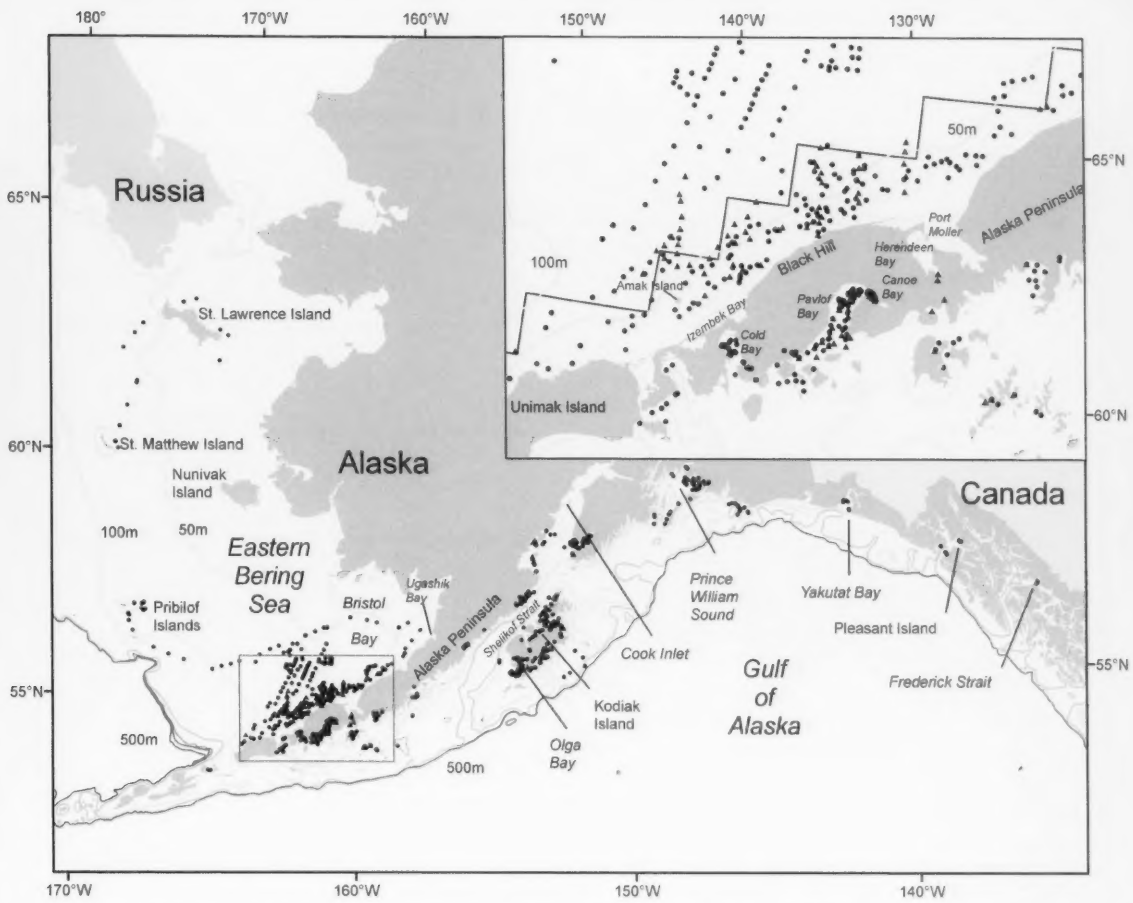

Figure 2.—Bottom trawl (●) and tangle net (▲) sampling locations during red king crab exploratory surveys conducted by the *Tondeleyo* and *Dorothy* in 1940, and by the *Dorothy*, *Champion*, and *Locks* in 1941. The stair-step line within the inset map shows the approximate southern extent of the present day survey (the center of the southernmost stations where most modern trawling occurs).

mentation, and overall impact on the other trawl surveys conducted during this era. Operations ranged from Frederick Sound in Southeast Alaska to Yakutat Bay, Prince William Sound, Cook Inlet, Kodiak Island, Shelikof Strait, the south side of the Alaska Peninsula, the southern Bering Sea, and north to St. Lawrence Island (Fig. 2). Inlets of all types were a major focus, with over 100 bays, coves, lagoons, ports, and harbors surveyed. Fishing ranged from late February through late November, so that seasonal changes in distribution and condition were observed. Over the years, the four vessels made 765 bottom trawl attempts and 151 tangle-net settings, caught over 39,000 red king crab, and reported various successes and failures due to conditions that would be encountered by future fishermen and researchers. Extensive results were published in a special May 1942 supplement to the FWS publication "Fishery Market News," and the hand-written data sheets are stored at the AFSC's Kodiak Laboratory; only a portion of those were accessed for this project. Thus, nearly all the results come from the publication.

Trawls vs. Tangle Nets

During this 1940–41 project, researchers compared the effectiveness and utility of catching crabs with bottom trawls and tangle nets in order to make recommendations to the U.S. fishing industry (FWS, 1942). The tangle nets had 45.7 cm (18 in) meshes, were 365.8 m (200 fathoms) long, 1.8 m (6 ft) high, and set vertically on the seafloor to entangle crab as they walked into the net (FWS, 1942: Fig. 26). Two general types of otter trawls were experimented with during the survey: the Atlantic

type had two seams and was low-opening (FWS, 1942: Fig. 28), whereas the Pacific type net had four seams and a higher opening (FWS, 1942: Fig. 29). Additionally, a modified Atlantic net with large meshes (20.3 cm or 8 in) and a larger Pacific trawl were tried. The trawls used wooden doors that were attached directly to the wing tips, so that door spread was essentially the same as net spread. Several conclusions and recommendations about the tested gears were made (FWS, 1942). Compared to tangle nets, the trawls were better at prospecting and exploring large areas, and large catches could be made in just a few minutes when crab concentrations were found. Also, trawls were nonselective, catching males, females, and juveniles equally, which was an advantage in assessment surveys. However, unlike tangle nets, trawls were destructive to the crab, catching and killing relatively immobile soft-shelled females on the spawning grounds. Also, trawl sampling was hit or miss in areas of high concentration, and trawls were often damaged in areas of rough seafloor, resulting in loss of catch.

Advantages of tangle nets were that they were effective and consistent in high abundance areas, and, in consideration for commercial fishing, they selected males over females, selected the more mobile hard-shelled crab over soft-shelled crab, and selected larger over smaller crab. The disadvantages were that tangle nets were poor for exploring, and the process of disentangling the captured crab was laborious and time-consuming. In 31 instances where both gears were fished in the same locations, with a 90 min soak for the tangle net and a 90 min set and retrieval period for the trawl, the tangle nets caught 50% more males (FWS, 1942). In overall catches, the tangle net males averaged 3 pounds heavier than those in the trawls (FWS, 1942).

Red and Blue King Crab Distributions

Red king crab were caught in a majority of the fishing attempts, and the crab ranged from Yakutat, through the Gulf of Alaska, and along the south and north sides of the Alaska Peninsula (FWS, 1942). In the southeast Bering Sea the largest catches were made along the Black Hill area, from Izembek Bay to Port Moller (Fig. 2). On the south side of the Alaska Peninsula, Pavlof and Canoe Bays had the highest catches and "were the most promising of all the Pacific [non Bering Sea] regions visited" (FWS, 1942:p. 57). Olga Bay had the highest catches in the Kodiak Island area. No great concentrations of blue king crab, *P. platypus*, were discovered, but they were abundant in the northern Bering Sea around the Pribilof, St. Matthew, and St. Lawrence Islands, where they replaced the red king crab. Isolated populations of blue king crab were found in Herendeen Bay on the north side of the Alaska Peninsula, Olga Bay on Kodiak Island, and a single blue king crab was found off Pleasant Island in Southeast Alaska.

While the 1940–41 survey was exploratory and conducted largely by personnel without experience for this type of research, the results clearly indicated the vast amount of red king crab biomass in the southeast Bering Sea. In Bristol Bay and adjacent waters (to long. 165.3°W), 19,162 red king crab were collected in 214 successful tows (about 80 crab per hour of effort) during April–September 1941. For reference, today's standard survey of the same general area collects an average of less than 2,000 red king crab, or about 8 crab per hour of effort. Some of this tenfold difference in crab density can be attributed to the fact that today's survey, although intended to cover the entire range of the Bristol Bay red king crab stock and to estimate its abundance, does not trawl within the high-density spawning grounds inshore of the "standard" survey boundary (Fig. 2).

Of the 214 tows conducted in red king crab habitat during 1941, only 9% caught no red king crab; by comparison, 50–60% of today's Bristol Bay survey tows are devoid of red king crab (Dew and Austring, 2007). From Unimak Island east along the Alaska Peninsula to Ugashik Bay, the 1941 Bristol Bay survey was divided into two areas—inshore and offshore. The offshore operations were conducted in waters 55–185 km from shore where males were more abundant (5,159 males caught vs. 1,513 females). The inshore operations, extending 55 km from shore, accounted for a greater proportion of the survey crab and the catches were generally dominated by females (7,539 females caught vs. 4,951 males).

The 1941 survey was the only one to describe the Bering Sea distribution of adult red king crab during the mating season on spawning grounds within 5–40 km from shore. The largest catches were made on these nearshore grounds along the western end of the Alaska Peninsula between Amak Island and Port Moller (FWS, 1942). The largest catch (3,188 crab, 57% females) was taken on 1 May in a 1.5 h tow in 38–44 m between Amak Island and Black Hill (Fig. 2). This catch was so heavy, estimated at 8,200 kg (9 tons), that it stopped the vessel, perhaps limiting the total catch.

Based on several tows in this area, investigators made the following observation: "Evidently huge beds of moulting females are mating with the males at this time of the year, and they are massed together in such a manner as to make them easy prey for a type of gear like the otter trawl, which scrapes along the bottom" (FWS, 1942: p. 72). While it is difficult to precisely define the areal extent of that aggregation, multiple tows indicated that the distribution of this molting-mating aggregation was continuous throughout at least a 140 km^2 area. This high-concentration spawning area, 37 km west of long. 162°W, is unprotected by any of the present-day trawl closures in the southeastern Bering Sea (Witherell and Woodby, 2005). Also, this spawning location (lat. 55.583°N, long. 162.583°W) is approximately 20 km inshore of today's stock-assessment survey boundary at lat. 55.7°N, long. 162.8°W, suggesting that large numbers of adult crab would be unavailable to a survey that was conducted during spawning but which did not extend inshore of the standard-survey boundary (Dew, 2008).

The second-largest catch in the 1941 survey (1,422 crab, 73% females) was

taken on 2 May in a 1 h tow in 44–46 m between Black Hill and Port Moller (Fig. 2). Again, the location (lat. 56.033°N, long. 161.567°W) of this large (>200 km^2) spawning aggregation was about 20 km inshore of today's survey boundary running between lat. 56.0°N, long. 162.2°W and lat. 56.3°N, long. 161.5°W off Black Hill–Port Moller. Similar to the dense aggregation of females off Amak–Black Hill, the females here, 93 km farther east along the Alaska Peninsula, were in a soft or molting condition in early May that resulted in most of them dying upon capture.

According to the 1942 report, trawl catches along the Alaska Peninsula diminished moving from Port Moller eastward "until a drag off Ugashik (lat. 57.667°N, long. 158.217°W) resulted in a 'skunk' haul" (FWS, 1942: p. 74). Today, this same area of Bristol Bay east of Port Moller, an area characterized by low crab abundance and little trawling activity (Dew and McConnaughey, 2005: Fig. 3), is protected from trawling as part of the Nearshore Bristol Bay Trawl Closure, which includes all waters east of long. 162°W.

Figure 3.—The University of Washington's research vessel *Alaska* during the Alaska Fisheries Science Center's 1992 U.S. West Coast bottom trawl survey. Photo credit: Mark Zimmermann.

Other Species

Vast quantities of flatfishes, *Pleuronectidae*, were taken as bycatch in the Bering Sea, though flatfish caught in Cook Inlet were of better quality (FWS, 1942). Catches of cod, *Gadus macrocepahlus*, were low, but it was hypothesized that this was due to using low-rise trawls and that the distribution of large cod extended farther north into the Bering Sea than had been believed previously. Aside from red king crab, Canoe Bay was noteworthy for large catches of flatfish and Tanner crab, *Chionoecetes* sp., which ranged up to 4,000 individuals in a 30 min tow.

Prince William Sound only yielded small quantities of fish. Although not mentioned in the publication, catches of "hake" or "silver hake," but without scientific names, were recorded on the individual data sheets from the shallows on the north side of the Alaska Peninsula, ranging up to 3,200 kg (7,000 lbs) in a 90 min bottom tow. It is unclear if the fish species referred to as "hake" was Pacific hake, *Merluccius productus* (Robins et al., 1991), which is not reported from Bering Sea surveys (Acuna and Lauth, 2008).

Another fish species listed on some of the same data sheets, but never within the same hauls, is referred to as "pollock," which was more common and presumably meant walleye pollock, *Theragra chalcogramma*, the most abundant species in the Bering Sea (Acuna and Lauth, 2008).

Interruption

Alaska red king crab exploratory cruises were discontinued during World War II, 1942–45, but at the end of the war the potential for harvesting underutilized marine resources reported from the 1940–41 explorations resulted in the government-financed conversion (via the Reconstruction Finance Corporation or RFC) of the *Pacific Explorer* into a factory processor and the construction of four smaller fishing vessels; the *Alaska*, *Washington*, *Oregon*, and *California* (Greenwood, 1982). Part of the vessel lease agreement from the RFC to the Pacific Exploration Corporation (PEC) included allowing government researchers to participate in the cruises (Greenwood, 1982). To complement this vessel construction effort, a North Pacific Exploratory Fishing and Gear Research (EF&GR) program was established at the FWS's Montlake Lab in Seattle in 1948 (Greenwood, 1982). During this era, EF&GR staff participated in three individual vessel cruises in 1947, 1948, and 1949; a ten-vessel fishing cruise with the *Pacific Explorer* factory processor in 1948; and a 1957 exploratory cruise aboard the *Tordenskjold*.

Alaska 1947

The 1947 cruise was a private venture to catch, process, and freeze Bering Sea red king crab, operated by the PEC using the RFC-purchased vessel *Alaska* (Fig. 3) (King, 1949). An observer from the International Fisheries Commission (IFC, now the International Pacific Halibut Commission or IPHC) tagged halibut while an observer from the FWS

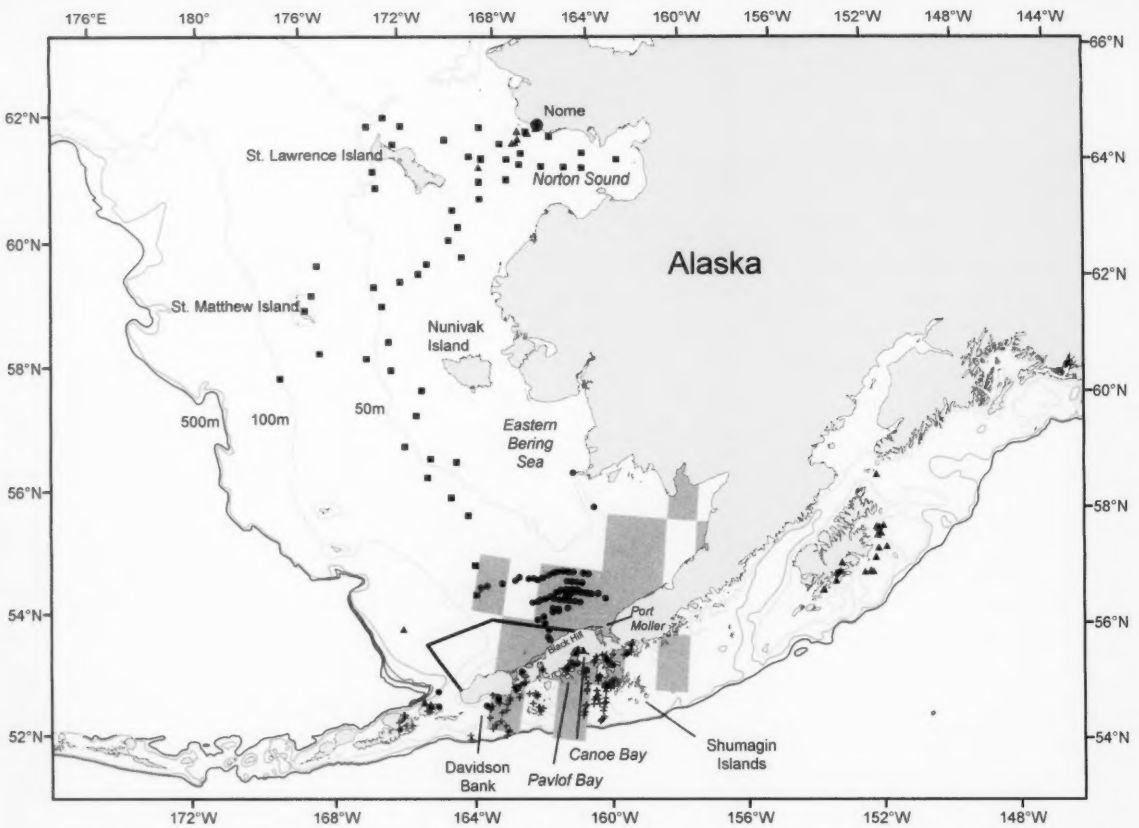

Figure 4.—Bottom trawl sampling locations during the *Alaska* 1947 (●), *Washington* 1948 (▲), and *Deep Sea* 1949 (■) red king crab exploratory cruises. Bottom trawl, shrimp trawl, and pot sampling locations (+) are shown for the 1957 *Tordenskjold* exploration in the Shumagin Islands area. *Pacific Explorer* fleet sampling effort of 1948 is only shown in one degree latitude/longitude blocks (■). The location of the Pot Sanctuary in the southern Bering Sea is shown with a solid black boundary (—).

collected information about crab and other groundfish. The original FWS data sheets are stored at the AFSC's Kodiak Laboratory and were not examined, but separate data sheets were also recorded by the IFC representative and these were accessed at the IPHC. While only data from the FWS publication (King, 1949) were utilized for this data rescue project, it is interesting to note that there are several discrepancies between the catch composition on the halibut data sheets and the FWS publication (King, 1949), suggesting separate data recording by the FWS and IPHC representatives during the cruise.

The 1947 cruise focused the most effort and caught the most marketable crab off the Black Hill area in the southeast Bering Sea, the region first prospected by the 1940–41 exploration (Fig. 4), thus confirming the high concentration of marketable male king crab and the ease of towing on the seafloor in this area (King, 1949). Over 14,000 red king crab were caught in only 148 trawl attempts. Large numbers of juvenile red king crab were caught in only two tows, one just offshore from the Black Hill area and the other about 65 km north from Port Moller.

The main impediments to trawling were large invertebrate catches which clogged and filled the net. While catches of halibut were low, the trawl caught tons of cod, pollock, and flatfish, which were discarded as waste, although King (1949) subsequently speculated that commercial fisheries might develop for these species. While, in general, only weights of major fish and invertebrate species were recorded, lengths of fish were measured from a few hauls and surface and bottom water temperatures were collected from 31 tows.

Pacific Explorer Fleet 1948

In early 1948, a fleet of 10 catcher vessels which included the *Bear*, *Borris*, *Dorothy* (Fig. 1), *Foremost* (Fig. 5), *Jeanette F.* (Fig. 6), *Kiska*, *Mars*, *Pearl Harbor*, *Sunbeam,* and *Tordenskjold* (Fig. 7), in support of the factory vessel *Pacific Explorer*, went to the Bering

Sea to catch, process, freeze, and can seafood (Wigutoff and Carlson, 1950). The PEC operated the factory ship and chartered the catcher vessels for a 90-day period of fishing. Fishing market specialist Norman Wigutoff (FWS, Ketchikan) and chief of exploratory fishing Carl Carlson (FWS, Honolulu) observed operations on the factory vessel and assisted with resolving problems with fishing methods, fishing gear, and canning operations (Greenwood, 1982). Logbooks were recorded by the catcher vessel skippers and provided to the FWS after the cruise. Summaries of catches from 1,099 trawl and 84 tangle-net sets were published in Wigutoff and Carlson (1950) but the actual locations are generalized, either by 10 minute or one degree latitude and longitude intervals (Fig. 4). Many fishing trials with insufficient catch and position information were not reported. The original data sheets are stored in the AFSC's Kodiak Laboratory archives but were not examined for this report.

The fleet started north from Seattle in the spring and met in early April in Pavlof Bay to await melt of the remaining Bering Sea ice and to experiment with crab fishing and processing methods in an area of known red king crab abundance (Wigutoff and Carlson, 1950). Within a 10-day period, a total of 31,657 male crab were taken from Pavlof and Canoe Bays—more than double what the *Alaska* had caught in the Bering Sea during a month of fishing in the previous year (King, 1949).

After the practice fishing in Pavlof and Canoe Bays, most of the fishing was done in the southeast Bering Sea, off the Black Hill area, slightly southeast of the fishing area of the 1947 *Alaska* cruise, and was of sufficient extent and duration to determine the general king crab reproductive migratory pattern. Trawls from 18 April to 5 July 1948 along the Alaska Peninsula from the western end of Unimak Island to Ugashik Bay collected more than 19,000 female red king crab and, similar to 1941, these crab were most abundant within the Unimak–Amak–Black Hill region.

The 12.7 cm mesh of the trawl's cod-end was sufficiently large to retain only the larger females, most of which would have been multiparous (carrying other than their first egg clutch and defined as ≥100 mm carapace length: Dew, 2008) crab forming the bulk of the broodstock (all gravid females). In the

Figure 5.—The schooner *Foremost* which was employed in the 1948 *Pacific Explorer* expedition for red king crab. Photo of the *Foremost* at Ketchikan, Alaska, courtesy of the Lokken collection (#223964) at the Museum of History and Industry, Seattle, Wash. Photo credit: Puget Sound Maritime Historical Society.

Figure 6.—The combination vessel *Jeanette F.* which was employed in the 1948 *Pacific Explorer* expedition for red king crab, docked opposite the *Deep Sea*, Lowell Wakefield's crab processing vessel. Photo of the *Jeanette F.* courtesy of the Joe Williamson collection (#5620) at the Museum of History and Industry, Seattle, Wash. Photo credit: Puget Sound Maritime Historical Society.

Figure 7.—The schooner *Tordenskjold* which was employed in red king crab explorations in 1948 and 1957 and in red king crab grid-patterned bottom trawl surveys in 1955–56 and 1958–59. Photo of the *Tordenskjold* courtesy of the Lokken collection (#209487) at the Museum of History and Industry, Seattle, Wash. Photo credit: Puget Sound Maritime Historical Society.

Unimak–Amak–Black Hill region, an area that was to become the original "Pot Sanctuary" (Beale, 1971) and referred to as Naab's "Special Sanctuary" in Dew and McConnaughey (2005), broodstock abundance (females per tow) in the 1948 survey was more than 20 times greater than that found in the Nearshore Bristol Bay Trawl Closure (all waters east of 162°W longitude), which is a protected area today. Large males had a similar distribution, with the highest densities in the Pot Sanctuary and the lowest densities east of Port Moller, within the region protected by today's trawl closure.

Again, tangle nets selectively caught male king crab and were better for conservation of the stock, but fishermen found disentangling the crab too difficult and resorted to tearing the PEC supplied nets to remove crab (Wigutoff and Carlson, 1950). Small flatfish, Pacific cod, walleye pollock (called whiting in the catch appendix of Wigutoff and Carlson, 1950), Tanner crab, and horsehair crab, *Erimacrus isenbeckii*, made up the bulk of the bycatch. Most of the small flatfish caught were considered too small for filleting and in too poor condition for marketing, so they were processed into fish meal, while most of the cod were large, in great condition, and processed at sea for commercial sales. One very interesting, accidental discovery was made during this cruise; an outbreak of respiratory illness among some of the workers on the *Pacific Explorer* resulted from an allergic reaction to breathing fumes from the crab cooking and canning process, crab asthma (Wigutoff and Carlson, 1950).

New bottom trawls were created for this catcher fleet based on experience from the 1940–41 survey—an Atlantic style trawl with a 29 m (95 ft) headrope and a 36 m (118 ft) footrope and a Pacific style trawl with a 25.3 m (83 ft) headrope and a 30.8 m (101 ft) footrope (Wigutoff and Carlson, 1950). Fishermen preferred the Atlantic over the Pacific trawl. The tangle nets were 1.8 m (6 ft) tall curtains of 40.6–45.7 cm (16–18 in) mesh 274.3 m (150 fathoms) long that rested on the seafloor.

Washington 1948

Ownership of the *Washington* was transferred from the PEC to the Montlake Lab in July 1948 (Greenwood, 1982) through special Congressional funding, which also supported vessel operations (Ellson et al., 1949). That fall the BCF used the vessel to explore the Norton Sound and St. Lawrence Island area (Fig. 4) of the northern Bering Sea, complementing previous research farther to the south. The first tow was not attempted until mid-September off of Nome and bad weather quickly forced the cruise south. On the way back to Seattle, three trawl hauls were conducted in Pavlof and Canoe Bays, resulting in the bulk of the red king crab catch of the entire cruise (194 of 212 crab). Unfortunately, the Canoe Bay crab were mostly brooding females and therefore, despite the large catch, further trawls were abandoned to avoid disturbing the nursery area. In the logbook for 3 October 1948, J. G. Ellson wrote "Canoe Bay population apparently all female and young crab this time of year also nursery area for flatfish as all taken were small. Believe Bay should be closed to fishing at least at this time of year, possibly permanently." Interviews with residents of coastal communities indicate that sea lions had recently increased rapidly in abundance and their predation had reduced cod and halibut abundance, but this is not supported with scientific observations.

The *Washington* traveled about 11,455 km (6,185 miles) during the 2-month cruise and completed only 32 bottom tows in a month of fishing (Ellson et al., 1949). After the return to Seattle, whole, frozen samples of rock sole, *Lepidopsetta* sp.; yellowfin sole, *Limanda aspera*; flathead sole, *Hippoglossoides* sp.; sand sole, *Psettichthys melanostictus*; and English sole, *Parophrys vetulus*, were partially thawed, filleted, refrozen, and compared with local flatfish. Laboratory analysis demonstrated that water loss upon thawing was comparable to local fish and the Alaska flounder fillets were rated higher for color, flavor, and texture at local fish markets. Thus, some of the bycatch or waste fish species from the 1940–41 exploration (FWS, 1942), the 1947 *Alaska* cruise (King, 1949), and the 1948 *Pacific Explorer* fleet cruise (Wigutoff and Carlson, 1950) were shown to be marketable, perhaps due to improved flesh quality and the late summer period. The authors of the 1949 Fishery Leaflet (J. G. Ellson, B. Knake, and J. Dassow) all participated in the

cruise, which later became known as Exploratory Cruise #1. The original log book is archived at the AFSC.

Deep Sea 1949

The 1949 cruise was conducted aboard the chartered vessel *Deep Sea* (Fig. 8), another RFC venture operated by Lowell Wakefield's Deep Sea Trawlers (later called Wakefield Seafoods) (Greenwood, 1982). The northern Bering Sea and Norton Sound area (Fig. 4) were finally explored on this cruise in the relatively good weather of summer, but found only 115 red and blue king crab in 51 tows (Ellson et al., 1950). No concentrations of any commercial species were found in the north and the seafloor north of St. Lawrence Island was too abrasive and rocky to trawl. Three catches exceeding 1,000 juvenile Tanner crab per 60 min tow were recorded from south of St. Lawrence Island, north of St. Matthew Island, and south of Nunivak Island. Some fish weights and lengths were collected and some stomach contents analysis was performed. Bottom samples were collected with a sounding lead, and catch data were related to water temperatures and depths. As in the 1948 *Washington* cruise, the small flatfish were reported to be in good condition. The bottom trawl was described as an Iceland trawl and dimensions were reported in a FWS Fishery Leaflet (Ellson et al., 1950). The *Deep Sea* 1949 cruise became known as Exploratory Cruise #2. The original data sheets, which list the FWS participants as J. G. Ellson, Donald Powell, Henry Hildebrand, and Ernest Dietrich, also provide net diagrams, some fish lengths, and stomach contents and are also archived at the AFSC.

Tordenskjold 1957

The *Tordenskjold* was chartered with Saltonstall–Kennedy Act funds in 1957 to explore for commercial quantities of red king crab in the region from Davidson Bank to the Shumagin Islands (Fig. 4) because of the large red king crab catches in Pavlof and Canoe Bays taken during the 1940–41 exploration (Johnson, 1959), during the spring of 1948 by the *Pacific Explorer* fleet (Wigutoff and Carlson, 1950), and during the fall of 1948 by the *Washington* (Ellson et al., 1949). Despite prospecting with a bottom trawl, a shrimp trawl, and king crab pots, no large quantities of red king crab were found. There were several catches of shrimp exceeding 450 kg (1,000 lbs), especially at the edge of Pavlof Bay, but the largest commercial trawl catch was 2,300 kg (5,000 lbs) of cod. Small catches of Pacific hake, ranging from 1 to 10 fish, were recorded in five otter trawl tows, including three which also had walleye pollock, again indicating the presence of a population of the fish in this area. Water temperatures were not recorded but 134 substrate observations were made.

Figure 8.—The side trawler and fish and crab factory processor *Deep Sea*, built by Lowell Wakefield's Deep Sea Trawlers company later renamed Wakefield Seafoods. Photo courtesy of the Joe Williamson collection (#3342-4) at the Museum of History and Industry, Seattle, Wash. Photo credit: Puget Sound Maritime Historical Society.

Monitoring/Gridded Surveys 1955–61

The era of long-term monitoring and grid-patterned red king crab bottom trawl surveys, designed for abundance estimates and stock monitoring, began with strong international cooperation. The International North Pacific Fisheries Commission (INPFC) was established in 1952 and initiated a cooperative U.S.–Japan red king crab monitoring program in 1954 (INPFC, 1954a) out of concern that the stock was already being fully exploited in the Bering Sea (INPFC, 1954b).

Prior to the official start of this cooperative program, in April 1953, BCF crab biologist Takashi Miyahara was transported to the Japanese king crab factory processor *Tokei Maru* near Amak Island by the *Deep Sea* (Fig. 8) so Japanese fishing operations could be observed. The *Deep Sea* also hosted a Japanese crab biologist to observe U.S. fishing operations (Miyahara, 1954). No U.S. research cruise was conducted in 1954, but biologists joined the *Deep Sea* during king crab commercial trawling operations in the Bering Sea and tagged 1,108 male king crab on the carapace or legs with Peterson disc tags affixed with nickel pins (INPFC, 1956). Since crab grow by shedding their integument, this tagging method was quickly abandoned and never repeated, but 28 of the 61 tags returned during 1955 had stayed on the crab for more than a year, leading to the serendipitous discovery that adult male crab do not molt every year. A study during trawling operations of the *Deep Sea* showed that soft-shelled (recently molted) males and females suffered high mortalities, ranging from 30% to 80%, as a result of being captured in trawls.

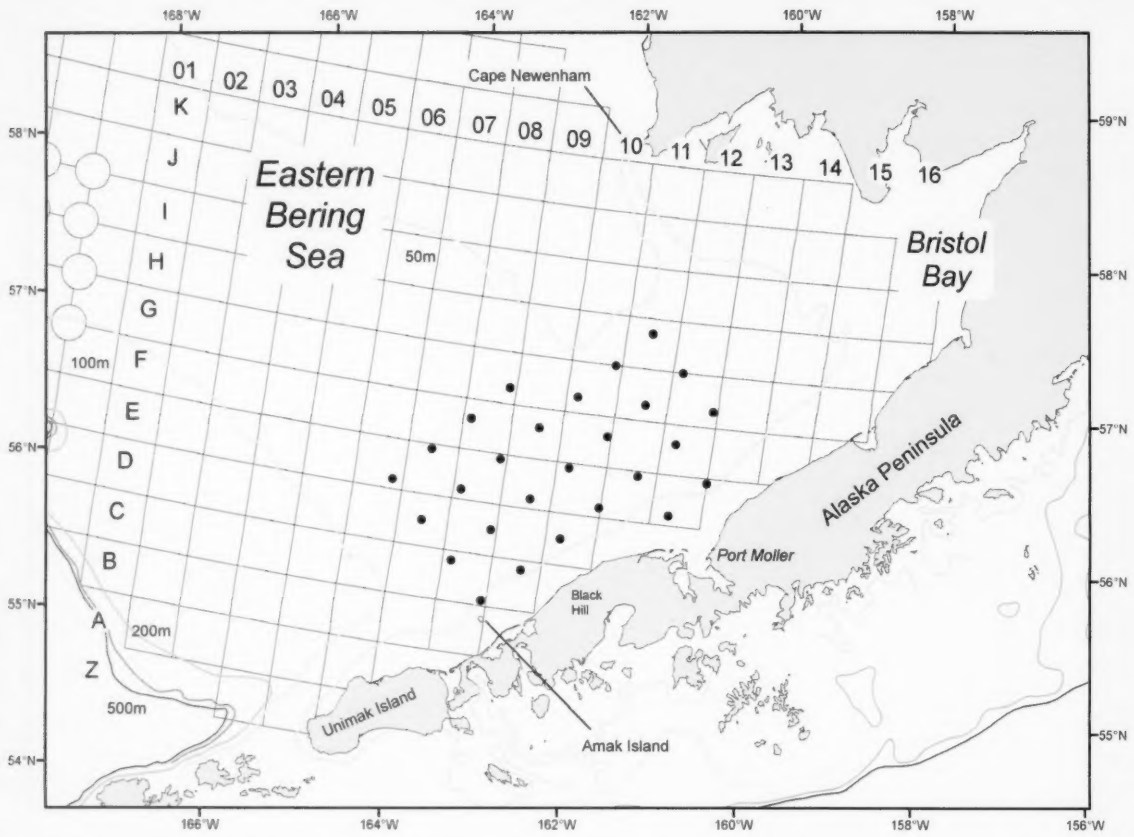

Figure 9.—Bottom-trawl stations from the first Bering Sea gridded bottom trawl surveys conducted by the *Tordenskjold* in 1955 and 1956 (actual trawling locations omitted for clarity). All stations were sampled in both cruises, except for the station near Amak Island, which was only sampled in 1956. Current Alaska Fisheries Science Center Bering Sea station sampling grid is shown for comparison of station locations.

Starting in 1955, most of the U.S research effort was allocated to preplanned, grid-patterned bottom trawl surveys conducted by chartered vessels with BCF biologists onboard. Summaries of findings from these cruises were published in INPFC annual reports, and findings from specific experiments conducted during these trawl surveys were published in journal articles, but the trawl survey results were never published. All information reported here is from the original logbooks kept aboard the vessels during the surveys and from handwritten data summary sheets found with the logbooks, which are archived at the AFSC's Kodiak Laboratory. Additionally, there was a cooperative arrangement made between BCF biologists and the University of Washington's Department of Oceanography to collect water temperatures, salinity, dissolved oxygen, water samples, and other data during government salmon explorations (Collins, 1956), and this practice was extended to the red king crab surveys, but not all of these data have been found.

Tordenskjold 1955

The first trawl survey with preplanned stations was conducted aboard the *Tordenskjold* (Fig. 7) in the summer of 1955 working on a 26-station (INPFC, 1956) diagonal grid (14′ latitude by 25′ longitude intervals) covering the southeast Bering Sea between Amak and Port Moller (Fig. 9). Initially the biologists tried to use traps to catch the crab, but after the traps were set, they were too difficult to relocate due to rough weather and high seas, which often dragged the traps far away (INPFC, 1956). (The problem of relocating the traps was solved by utilizing wire-mesh reflectors on buoys that could be seen on radar (Johnson, 1959; Blackford, 1979)). Additionally, it was felt that the traps tended to catch more males than females. Therefore, the trap effort was abandoned after a few days and four rounds of half-hour tows on the stations commenced between 10 June and 16 July, for a total of 104 hauls. Red

king crab were caught in every haul, ranging up to 99 males and 85 females within the same general area as the 1947 *Alaska* and the 1948 *Pacific Explorer* fleet surveys.

However, the survey did not sample the inshore area which had proven to be important in the 1940–41 survey, and no large crab concentrations were found, and plankton hauls failed to catch any crab larvae. "Hake" were recorded routinely during this cruise, and it is presumed that these were actually pollock, *T. chalcogramma*. Surface and bottom water temperatures were collected during each of the four rounds of trawling during this cruise and were available from the original data sheets, though they were not mentioned in the 1955 summary provided by Gast et al. (1956). The U.S.–Japan biologist exchange program continued, with Takashi Miyahara (FWS) working on the *Tokei Maru* and Seiwa Kawasaki (Japan Fishery Agency) working aboard the *Tordenskjold*.

Tordenskjold 1956

With the addition of a 27th station placed near Amak Island (Fig. 9), the same stations were trawled by the *Tordenskjold* in 1956 in two rounds, 9–20 July and 20 Aug.–1 Sept. (INPFC, 1957). Several tows were added for crab tagging, one of which, about 140 km northwest of Port Moller, caught an estimated 6,800 kg (15,000 lbs) of new-shell males (75–230 mm carapace width) in 60 min. The net was so heavy that it had to be cut open so that the catch could be spilled at sea and the net retrieved. A second 30 min tow in the same area caught 1,361 males and 2 females (roughly 4,500 kg). If accurate, the weight of both of these catches exceeds the largest catch of red king crab in the AFSC database, RACEBASE (3,300 kg). Several other tows covering an expanse greater than 200 km^2 helped define the minimal extent of this male aggregation, although the edges of the aggregation were not located.

In both 1955 and 1956, apparently only the start position and direction of each tow were recorded. Navigational methods used are not clear, but a note from the logbook on 18 July 1956, mentions latitude taken from "Sun line and Loran." Fishing effort was recorded as the approximate time the net was set down to the start of haulback. Fred Cleaver (BCF) participated in the 1956 survey and C. E. Atkinson is mentioned as a cruise coordinator. Temperature and salinity data from the 1956 survey were published in Love (1959).

Mitkof 1957

The *Mitkof* was chartered for the 1957 survey, which initiated a new, square-gridded station pattern (INPFC, 1958) with stations at intervals of 37 km (20 nmi) (Fig. 10). This station pattern, with rows designated by letters and columns designated by two-digit numbers, is still used today (Acuna and Lauth, 2008), but the reason this new station pattern supplanted the 1955–56 station pattern is not documented. This cruise sampled 77 stations in a single round of 30 min tows from 24 June through 25 July. This roughly tripled the spatial coverage from the first two gridded surveys, extending sampling north to Cape Newenham, east into Bristol Bay, and southwest to Unimak Island, but at the expense of conducting additional rounds of sampling.

Towing could not be completed near Unimak Island because of the rough seafloor and, as in the 1955 and 1956 surveys, the inshore spawning ground areas were not included in the survey design. Notes on the original data sheets indicate that radar was used to determine distance of tows and a roller ("lawnmower") with two recording devices was attached to the cod end of the net to record distance traveled along the seafloor (Carey and Heyamoto, 1972). The net spread was calculated by measuring the angle of the main wires to floats attached to the doors with a rangefinder (doors were directly attached to the net wings). Additionally a wire meter was used to try to measure the amount of main wire set for each tow, but it did not work well. No enormous red king crab catches were made as in the 1956 survey, but red king crab were caught at all but two stations, ranging up to 281 males at station E08 and 88 females at G12. A single male blue king crab was caught at I10, the only one identified during the 1955–1961 time series. A summary of the 1957 survey was published as a USFWS progress report (USFWS, 1957) which includes information on tag returns, growth rate estimates, and the first quantitative population estimates based on fishing effort, making it the first U.S. king crab stock assessment (USFWS, 1957; INPFC, 1958). Fred Cleaver participated in the 1957 survey.

Tordenskjold 1958

The *Tordenskjold* 1958 survey (Fig. 11) essentially replicated the 1957 survey, except that tows were increased to 60 min duration and there were two rounds of trawling, 29 April–3 June and 8 June–11 July (INPFC, 1959). This early round of trawling is temporally coincident with the early May catches of inshore mating aggregations sampled in 1941. For the first time, a more southern row of stations, Row Z, was added to the survey grid, although no reason for this addition was documented. A total of three inshore stations were added to the 1957 station pattern, Z05, A06, and D11, while station E13 was permanently deleted from the survey. Because the 1958 survey was conducted twice, once during spawning in April–June and again in June–July during the return of post-spawning red king crab, our analysis of the original data revealed the effects of emigration and immigration on survey estimates of abundance, distribution, and sex ratio.

Consistent with the influx of post-spawning crab from areas inshore of the survey area, the average density of male and female crab in the survey area increased between the two sampling phases, from 59.0 crab/tow during spawning in the 29 April–3 June phase, to 104.9 crab/tow in the 8 June–11 July phase. More specifically, the density of multiparous females (≥100 mm carapace length) in the survey area more than doubled between the two sampling phases, from 14.9 crab/tow during spawning, to 41.6 crab/tow in the June–July phase, as the newly mated crab returned to the survey area.

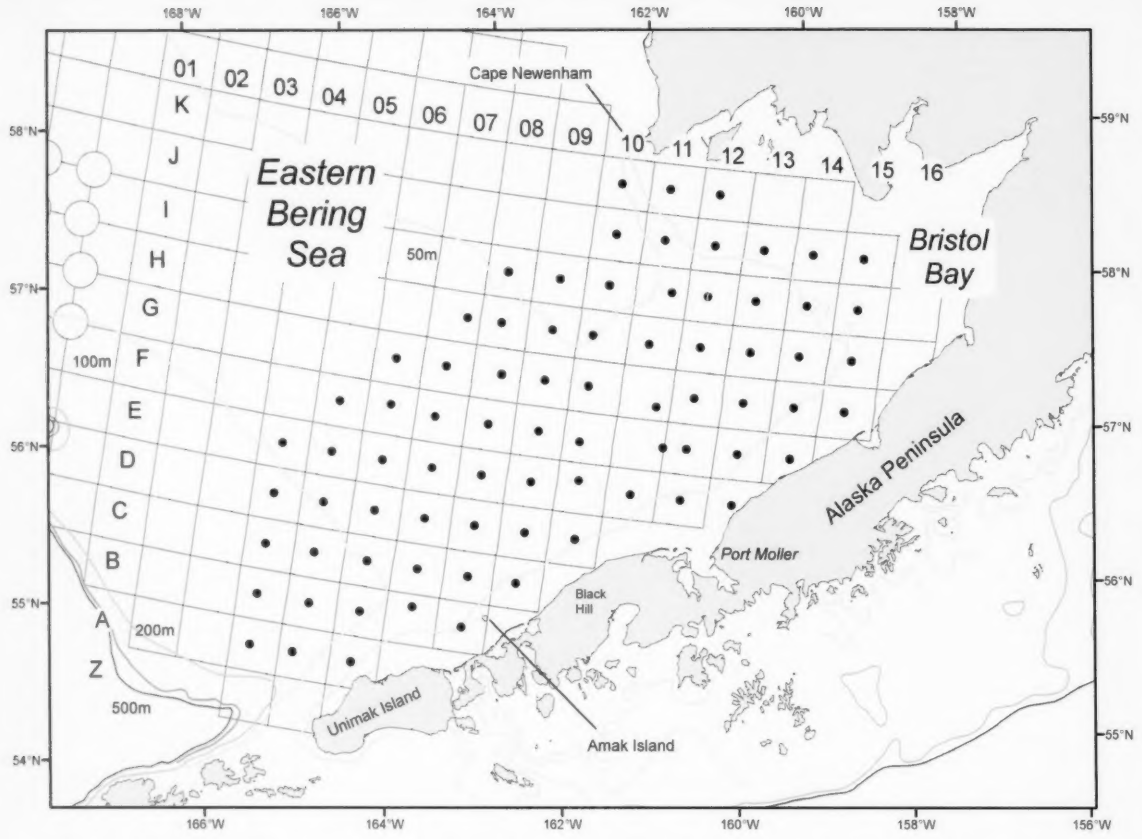

Figure 10.—Starting position of bottom trawl hauls during the *Mitkof* 1957 red king crab cruise. This is the first survey conducted on the current sampling grid.

Also, because the proportion of mature females participating in annual spawning is larger than that of the mature males (Dew, 2008), the sex ratio changed dramatically between sampling phases. During April–June 1958, while a relatively large proportion of the female population was outside the sampling area, mature males inside the sampling area were 0.60 of the mature population. In June–July, as predominantly female mature crab returned to the sampling area, the sex ratio changed to a male proportion of 0.39.

We believe the two-phase design of the 1958 survey was instrumental in demonstrating the importance of survey timing with regard to red king crab spawning movements. Because of substantial immigration by gravid females into the standard survey area after spawning, a Bristol Bay trawl survey conducted during red king crab spawning is unlikely to provide entirely reliable data with respect to stock abundance, sex ratio, or mating success (Dew, 2008). Nor is such a survey likely to provide information with which to evaluate habitat essential to a red king crab broodstock returning from inshore spawning grounds to settle into an 11-month period of egg incubation.

For example, our analysis of the April–June sampling in 1958 indicated that only 5% of Bristol Bay's multiparous broodstock was present at eight nearshore stations in the Unimak–Amak–Black Hill region (stations Z05, A05, A06, B05, B06, C06, C07, C08). However, by early July, after multiparous crab had returned from spawning, 34% of the total Bristol Bay multiparous broodstock was found at the same eight stations. Similarly, at two stations off the west end of Unimak Island (stations Z05 and A05), the broodstock density in 1958 increased from 1.5 crab/tow in April–June to 281.5 crab/tow in June–July. Based on such information the Unimak–Amak–Black Hill region was set aside during the 1960's as a special king crab refuge known as the "Pot Sanctuary," where trawling was prohibited (Simpson and Shippen, 1968; Naab, 1968a, b, 1971; Beale, 1971). Today the former Pot Sanctuary (Fig. 11) is a heavily trawled region known

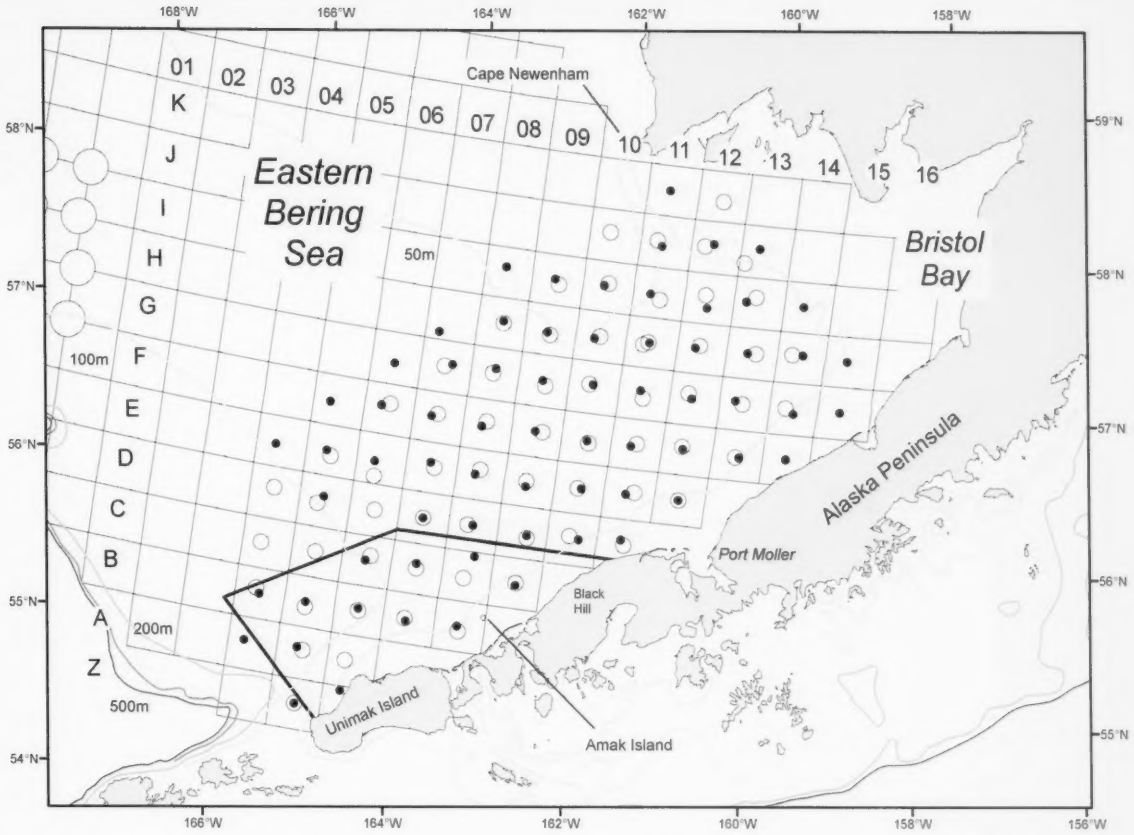

Figure 11.—Starting position of bottom trawl hauls during the first (●) 29 April–3 June and second (○) 8 June–11 July rounds aboard the *Tordenskjold* in 1958. The location of the Pot Sanctuary in the southern Bering Sea is shown with a solid black boundary (—).

as "Cod Alley," from which red king crab have largely disappeared (Dew and McConnaughey, 2005).

Biologists summarized the 1958 Bering Sea king crab trawl survey abundance data, tag releases and commercial fishery returns, growth estimates, meat content of new vs. old-shell crab, and gear selectivity (INPFC, 1959). An abundance estimate using tag returns was calculated, but these results unexpectedly differed from the trawl survey abundance estimate. Again, a gear comparison demonstrated how Japanese tangle nets selected for larger crab than the survey trawl net. This was the first survey for which a cruise plan was found. Fred Cleaver and Henry Sakuda (BCF) conducted the first round of sampling, Takashi Miyahara and Frank Hebard (BCF) conducted the second round, and both Cleaver and Miyahara are listed as cruise coordinators.

Tordenskjold 1959

In 1959, the *Tordenskjold* was chartered again for the red king crab survey (INPFC, 1960). Round 1 of trawling, 2–19 May, which occupied only the western two-thirds of stations due to rough weather (Fig. 12), consisted of 60-min tows. Round 2, 2–20 Aug., was a dedicated tagging cruise, in which repeated trawls for 30 or 60 min were made in a few locations, such as off Unimak Island, to meet a tagging quota (Fig. 12). Similar to the 1958 survey, broodstock density at stations Z05 and A05 off Unimak Island increased from 7.5 crab/tow in May to 98.3 crab/tow in August. Data from the early summer and late summer tows in the 1958 and 1959 surveys highlight the problem of relying on May–June surveys conducted during spawning to evaluate the importance of coastal waters off Unimak and Amak Islands as habitat for the Bristol Bay red king crab broodstock.

Without the knowledge of the results from the 1958 and 1959 surveys, the significant difference of having an early or late bottom trawl survey, especially in regard to the sampling of the inshore spawning areas, can result in misspecification of habitat that is essential to red king crab. For example, based on May–June data from red king crab surveys

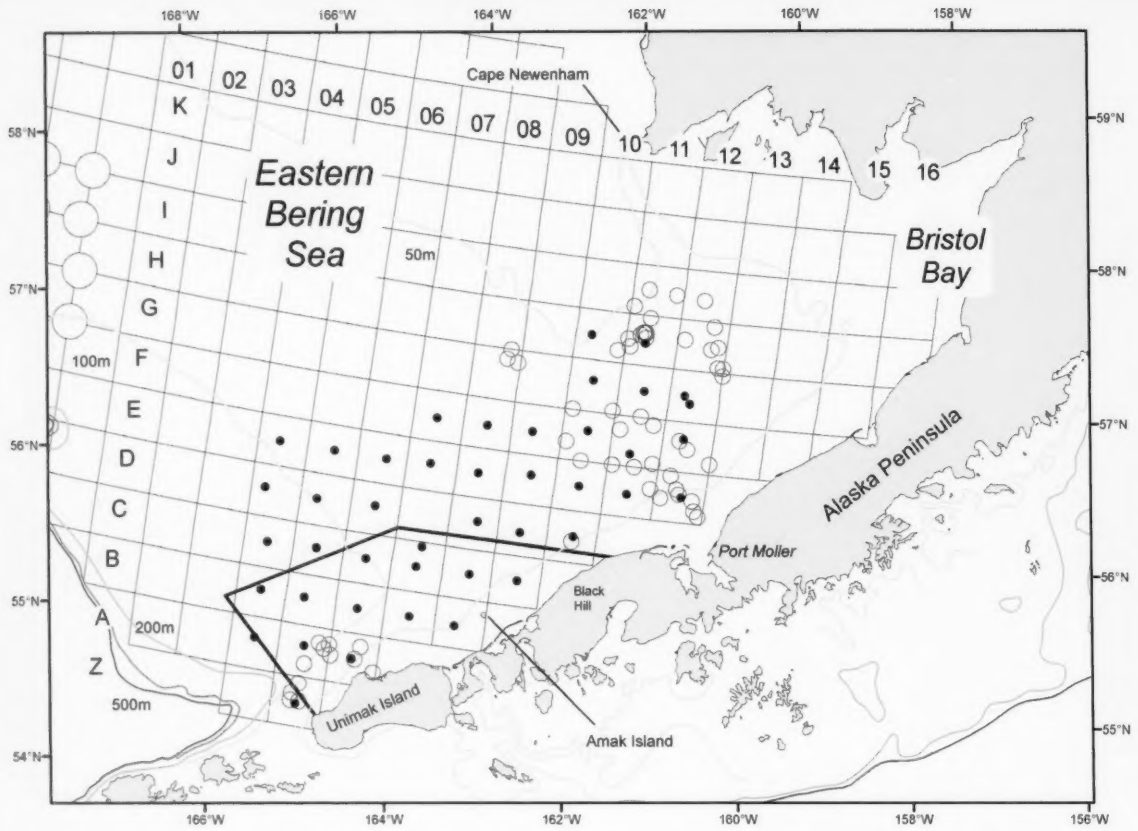

Figure 12.—Starting position of bottom trawl hauls during the *Tordenskjold* 1959 cruise (•) 2–19 May and red king crab tagging sites (o) 2–20 August. The location of the Pot Sanctuary in the southern Bering Sea is shown with a solid black boundary (—).

during 1987–2002, the environmental impact statement on essential fish habitat (NMFS, 2005) concluded that the area north of Unimak Island historically was unimportant as broodstock habitat (Dew, 2008). However, it is unlikely that the Pot Sanctuary (Fig. 12), America's first trawl-free refuge established specifically for red king crab (Naab, 1968a), would have been established if the Unimak–Amak–Black Hill region (now Cod Alley) was unimportant as habitat for Bristol Bay red king crab.

The 1959 cruise plan lists BCF scientists Sakuda and Hebard as participants in the station sampling round, Miyahara and Hebard as participants in the tagging round, and Miyahara as the cruise coordinator. Samples of invertebrates were retained from trawl hawls, and special dredge samples from the 1958 and 1959 surveys were taken for identification by Patsy McLaughlin (BCF) (McLaughlin, 1963). Temperature data collected in 1958 and 1959 are summarized in the figures and Appendix B of McLaughlin (1963).

Paragon 1960 and 1961

The *Paragon* (Fig. 13) was chartered for the 1960 (Miyahara, 1961) and 1961 (Shippen and Miyahara, 1962) surveys, each of which conducted 60-min tows in a single round. The surveys in both years were intended to cover a greater geographic extent so that the western, northern, and eastern red king crab distribution limits in the Bering Sea would be defined, but, in retrospect, this effort failed to completely encompass the bounds of the red king crab distribution. The 1960 survey was conducted late in the summer (2–30 Aug.) while the 1961 survey was earlier (7 July–4 Aug.).

The 1960 survey pattern (Fig. 14) was roughly equivalent to the greater spatial extent of the 1957 and 1958 surveys, while the 1961 survey concentrated on the southwest area, similar to the 1959 survey. Both surveys again had large catches of brooding females off of Unimak Island, in 1960 at stations C05, C06, and B06 and in 1961 at stations C06 and B06. Overall, crab catches were much lower in 1960 than in 1961, with the largest catches of males (n =

721) and females (n = 674) occurring at station E11 in 1961. The 1961 survey was the first to create new trawl stations on the corners of the grid pattern squares. These new stations proved to be, unfortunately, in a high abundance area of basketstars, *Gorgonocephalus eucnemis*, which coil their arms when disturbed and become entangled in the meshes of the trawl.

Cruise plans were found for both the 1960 and 1961 surveys. These documents describe the station pattern, sampling plans, trawl gear, and safety considerations for working on a vessel at sea. Surveys in both years used a 400 mesh Eastern type trawl, where the wing tips were connected directly to the doors. It is not clear if this same net was used for all the grid-pattern trawl surveys. The 1961 cruise plan has a short key for identifying fishes and the method for distinguishing hake and pollock is mentioned, along with a map showing that the distribution of hake, pollock, and cod is coincident in the area to the north of Unimak Island.

Hake were reported in catches in the vessel captain's logbook in 1960 but not in the scientist's data book on benthic species, where fish were rarely mentioned. In 1961, catches of between 100 and 300 lb of hake were recorded in four tows, all of which were in the southeastern Bering Sea, and pollock were caught in each of these tows, too. BCF scientists Doug Weber and Herb Shippen participated in the 1960 *Paragon* cruise but there were no IPHC staff (Herb Shippen[4]). Henry Sakuda, another BCF biologist (perhaps Alan Hazelwood), and Ray Hillson (IPHC) participated in the 1961 cruise (Shippen is listed as a participant in the cruise plan but he did not participate; Herb Shippen[4]).

Figure 13.—The vessel *Paragon* which conducted the 1960 and 1961 Bering Sea red king crab bottom trawl surveys. Photo (date 1937) courtesy of the Lokken collection (#224405) at the Museum of History and Industry, Seattle, Wash. Photo credit: Puget Sound Maritime Historical Society.

Epilogue

Organizations

Large-scale changes in the 1960's and 1970's in the fisheries research organizations involved in the Alaska red king crab program led to disruptions in the Bering Sea bottom trawl survey. The history can be traced to the Montlake Lab opening in Seattle in 1931, which provided office space for several different research groups, including the IFC, which was established in 1923. Due to the Montlake Lab program expansion and other factors, the IFC moved in 1936 (Atkinson, 1982) to the nearby University of Washington campus. Established in 1952, the INPFC, which provided a critical framework for international cooperation on the crab research and management in the Bering Sea, ended in 1992 and was replaced by the North Pacific Anadromous Fish Commission in 1993 (NPAFC, 1994).

Following Alaska statehood in 1959, an EF&GR base was established at Juneau, Alaska, in 1960 (Greenwood, 1982) and the responsibilities of the Seattle EF&GR base concerning Alaska commercial fisheries, including the Alaska Crab Investigation Program, were transferred to Juneau, although only two of the Seattle staff made the move north (Simpson, 1982). The 1961 red king crab survey was the last conducted by staff at Montlake, and the 1966 *Sonny Boy* king crab survey was the first by the staff at Auke Bay (Kirkwood and Hebard, 1967), but these data sheets have not yet been located.

During this interruption in the BCF Bering Sea trawl surveys in the early 1960's, the IPHC began their own time series by conducting bottom trawl surveys in the Bering Sea in 1963, 1965–66 (Best, 1970), 1967 (Best, 1969a), 1968–69 (Best, 1969b), 1970–72 (Best, 1974), and 1973–80 (Best and Hardman, 1982). These IPHC surveys were similar to the BCF surveys in that they occurred during the summer, utilized a 400 mesh eastern trawl (Best and Hardman, 1982) similar to the BCF trawl, and even used

[4]Shippen, H. Retired BCF and NMFS fisheries biologist, Personal commun. May 23, 2006.

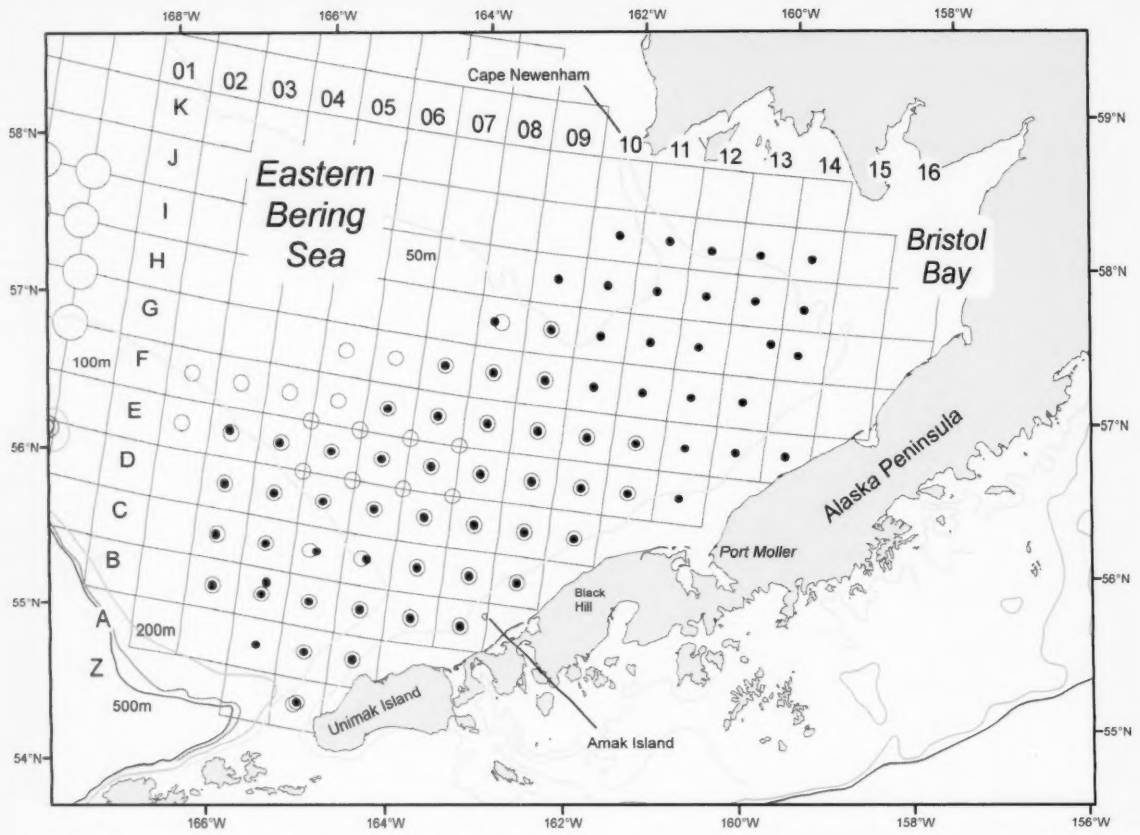

Figure 14.—Starting position of bottom trawl hauls during the *Paragon* 1960 cruise (●) (2–30 August) and during the *Paragon* 1961 cruise (○) (7 July – 4 August).

the charter vessel *Tordenskjold* in seven of the surveys (Best, 1970; Best and Hardman, 1982). These IPHC surveys were conducted on a 15' latitude and longitude diagonal grid more similar to the 1955–56 BCF surveys rather than the 1957–61 BCF surveys, but they still encompassed much of the same area. A letter from the IPHC director (F. Heward Bell) to the Juneau BCF director (Harry Rietze) mentions king crab data collected during the 1963 and 1965 IPHC surveys as well as the possibility of hosting a BCF biologist during the 1966 IPHC survey. A BCF red king crab biologist participated in the 1967 survey and collected crab data (Best, 1969a) but it is not known if similar crab data were collected on other IPHC surveys.

On 30 June 1964, the BCF red king crab research program was officially terminated in Seattle and the duties were transferred to Juneau (Shippen, 1965). Memos directing the transfer of all data sheets and records, from Seattle to the Juneau EF&GR base were written in 1966 and 1967, indicating that the program took several years to transfer. The Juneau EF&GR lab was moved again, to Kodiak in 1970 along with the *Oregon* (Greenwood, 1982). Annual Bering Sea bottom trawl surveys were conducted by Kodiak staff aboard the *Oregon* from 1971–80 (available in RACEBASE at the AFSC).

In 1970, Congress created the National Oceanic and Atmospheric Administration (NOAA), placing it in the U.S. Department of Commerce and incorporating the BCF and other marine components of the Bureau of Sport Fisheries and Wildlife to make National Marine Fisheries Service (NMFS) (Chandler, 1988). Several research programs at the Montlake Lab were united in 1971 to create the Northwest Fisheries Center (NWFC), one of four regional NMFS science centers in the United States, while the Auke Bay Laboratory was managed separately as one of four regional inshore and estuarine labs (Atkinson, 1982). In 1974, the Auke Bay Laboratory joined the NWFC (Atkinson, 1982), which was renamed the Northwest and Alaska Fisheries Center (NWAFC) in 1976. In 1989, the NWAFC was divided into the Northwest

Fisheries Science Center (NWFSC), which remained at the Montlake location in Seattle, and the Alaska Fisheries Science Center (AFSC), which had moved earlier to the new facility at Sand Point, also in Seattle.

In the early 1970's, the Montlake EF&GR base first became part of the NWAFC's Division of Marine Fish and Shellfish (MF&S); it later became part of the Resource Assessment and Conservation Engineering (RACE) Division which was primarily responsible for the newly created Marine Monitoring, Assessment and Prediction (MARMAP) Program (Greenwood, 1982). Additional staff, including the king crab researchers, were added to the MF&S Division for the MARMAP II program, splitting into the RACE and the Resource Ecology and Fisheries Management (REFM) Divisions in 1975 (Greenwood, 1982). Also in 1975, MARMAP, in coordination with the Bureau of Land Management's Outer Continental Shelf Environmental Assessment Program (OCSEAP), conducted the largest Bering Sea bottom trawl survey in terms of areal extent to date (Pereyra et al.[2]).

A follow-up survey in the spring of 1976 also covered a vast area (Smith and Bakkala, 1982). Together these surveys became recognized as the beginning of a new research program rather than the continuation and expansion of the earlier red king crab surveys, perhaps because the Kodiak Laboratory was still conducting Bering Sea red king crab bottom trawl surveys on the *Oregon*. Thus, the official start of the current Bering Sea trawl survey time series is 1975, and the title of that trawl survey report includes the phrase "In the baseline year of 1975," even though the gridded trawl surveys of 1955–61 are briefly mentioned in the text (Pereyra et al.[2]). Knowledge of the 1940–61 surveys and the findings of the biological sampling programs have been lost to the research community and largely forgotten.

Surveys

The Bering Sea bottom trawl grid survey is still conducted every summer, making it one of the oldest surveys of its kind in U.S. waters, although vessels, gear, and methods have changed over time, and there have been interruptions in the time series. The survey is typified by using bottom trawls for sampling the resource abundance, chartering private fishing vessels for research platforms, trawling only during daylight hours, and paying for the charters with external funding (as it has since the 1940–41 expedition). The scientific staff on each vessel typically includes a total of six biologists from the AFSC, two crab biologists from the Kodiak Laboratory, and four biologists generally focused on groundfish. The charter vessel crew conduct all the fishing with the trawl, both the vessel crew and scientific staff participate in sorting the catch, and the scientific staffers collect and record the catch data for their areas of expertise.

If the attempt at trap fishing at the beginning of the 1955 survey had been more successful, the whole time series for red king crab might have been based on baited pots rather than a bottom trawl. One substantial change in the use of bottom trawls in the trawl survey was that all of the older vessels lacked stern ramps, so catches had to be hoisted onto the deck by booms, which was a difficult and dangerous operation, especially in rough weather and on small vessels. Another substantial change in gear design is that the older survey trawls had the doors fixed to the trawl wing tips, defining a clear area swept, while the more recent trawls have the doors separated by dandylines, which act to herd mobile animals into the net (Somerton and Munro, 2001); the date and the reason for this change are unknown.

The survey's origin as a grid-patterned sampling program can be traced back either to the diagonal grid used in 1955–56 or the square grid first used in 1957, which is still utilized. The 1957 survey also marked the beginning of attempts to determine the length of seafloor contact to the net, to measure the distance across the opening of the net, to measure the amount of main wire used, and produced the first area-swept based biomass estimate, which was the first stock assessment (INPFC, 1958). King crab biomass estimates utilizing returns of tagged crab were attempted in 1958 and 1959. The extra, southern "Z" row of stations was first added to the survey in 1958, and the first corner stations were added in 1961, but any nearshore survey component directed towards the Unimak–Amak–Black Hill region spawning aggregations found in 1941 is no longer a standard part of the trawl survey.

Working closely with the fishing industry to conduct these surveys dates back to the first of all of these surveys in 1940–41, which was greatly facilitated by the cooperation of Lowell Wakefield and his king crab fishing company. It is hoped that these early surveys can be used to extend the current time series of catch data back at least 20 years prior to the official start in 1975. Additionally, the early surveys described in this manuscript include 510 surface water temperatures, 535 bottom water temperatures, 427 pairs of surface and bottom temperatures, and 1,262 substrate observations, which may prove useful for other projects.

Vessels

The fates of the red king crab survey vessels are as varied as the findings of the surveys for which the vessels were chartered. The *Mitkof*, built in 1940, continued fishing for many years after the 1957 charter, but it hit a rock and sank off Petersburg in southeast Alaska in 2004 (Loy, 2004). The *Tordenskjold*, built in 1911, is still berthed at Fishermen's Terminal, Seattle; it has conducted at least 14 other research cruises for the AFSC. The *Paragon* caught fire at sea and was lost a few years after its Bering Sea king crab trawl surveys in 1960–61; everyone was rescued when the ship burned (Shippen[4]). The University of Washington replaced its research vessel *Commando* with the *Alaska* in 1980 (Stickney, 1989) and operated it as a charter vessel for several years. The *Alaska* was chartered for at least 25 AFSC cruises which included the 1981 and 1983–1992 Bering Sea bottom trawl surveys. The *Alaska* completed its last AFSC survey in 1995 and was sold by the University in the late 1990's. The *Washington*, acquired by the Montlake Lab in July 1948, was sold in late 1948

and the money was applied toward the 1950 construction of the *John N. Cobb* (Greenwood, 1982), which was retired in 2008 (Orsi and Heard[5]). The *Oregon* was transferred to the NMFS Southeast Fisheries Science Center's EF&GR base in Pascagoula, Mississippi, but it was returned in 1969 for more Alaska cruises, becoming an official NOAA vessel in 1973 (Greenwood, 1982). It was decommissioned and transferred to the State of South Carolina in 1980 (Greenwood, 1982).

Industry

The cooperative efforts between the government and private king crab fishermen had a lasting impact on both entities, even though this mingling of efforts and the discoveries made have been largely forgotten. For example, the king crab asthma discovered during the 1948 *Pacific Explorer* expedition (Wigutoff and Carlson, 1950) was rediscovered and described as a new phenomenon over 30 years later at king crab processing plants in Dutch Harbor, Alaska (CDCP, 1982). As a result of the 1940–41 surveys, Captain Ellsworth F. Trafton of the *Dorothy*, Captain Harry Guffey of the *Locks*, and BCF Fishery Economist Leroy Christy (head of the 1941 cruise) became pioneers in the king crab industry (Blackford, 1979). A single, large BCF exploratory catch of crab in front of the Port Wakefield herring plant inspired Lowell Wakefield, son of the plant owner Lee Wakefield, to experiment with crab trawling and canning in the Raspberry Strait area and eventually to become the king crab industry leader (Blackford, 1979). The 1948 *Washington* cruise demonstrated that Bering Sea flatfish could be frozen and processed successfully for market in Seattle (Ellson et al., 1949).

Despite the poor crab catches by the *Deep Sea* during the 1949 charter, the money from the charter, along with successful king crab fishing trips before and after the charter, was a reversal of fortune that prevented the imminent bankruptcy of Lowell Wakefield's Deep Sea Trawlers (Blackford, 1979). While it might seem strange to describe a red king crab trawling operation for a species that is currently only associated with pot-fishing, pots were rarely used in that era. Trawling was a functional fishing method but the technology was rudimentary.

Wakefield solved navigational problems with the use of Loran, radar, and buoys for marking good fishing areas, and he solved technical trawling problems by hiring Boris Kanake (from the BCF) who replaced wooden rollers on the footrope with a ground-hugging, heavy steel footrope and designed a new, more efficient cod end. Additionally a deck winch enabled the crew to haul aboard large catches more easily and crab meat processing steps were streamlined. William Blackford was the primary captain of the *Deep Sea* for 7 years, but he retired from sea-duty in the mid-1950's, in part, in order to be closer to his family in Seattle (Blackford, 1979). Later, Captain Blackford helped his son Mansel G. Blackford to write an authoritative and highly readable account of Wakefield's company "Pioneering a modern business: Wakefield Seafoods and the Alaskan frontier" (Blackford, 1979). Mansel Blackford is currently a professor of history at Ohio State University.

Lowell Wakefield's red king crab company became successful and profitable despite other obstacles including rough weather, foreign and domestic fishing competition, the great 1964 Alaska earthquake, and the vast areas covered by his fishing, processing, and marketing operations (Blackford, 1979). When crab trawling was prohibited in Alaska state waters in 1960, it signaled the approaching end of the crab trawling era pioneered by Wakefield in the 1940's (Blackford, 1979). Such was the bond between industry and government that when the red king crab program was transferred from Seattle to Juneau, Takashi Miyahara quit the BCF and joined Wakefield's company as a manager in 1963 (Blackford, 1979).

Alaska king crab catches declined in the late 1960's, which led Wakefield's stockholders to accept a merger/buyout offer in late 1968 (Blackford, 1979). By 1971, most managers, including Miyahara, had left (Blackford, 1979). Lowell Wakefield is largely credited with being the father of the Alaska red king crab industry, and later in life he became an adjunct professor of fisheries at the University of Alaska. Since 1982, the Alaska Sea Grant College Program has coordinated an annual symposium series that bears his name.

Resources

Pacific Hake

There is great confusion among these cruises about the possible occurrence of Pacific hake, *Merluccius productus*, in some Bering Sea catches because of variations in the use of common names, the close physical similarity of Pacific hake and walleye pollock, and the widely held belief that Pacific hake do not occur in the Bering Sea. The common name for *Theragra chalcogramma* is given as either "Alaska pollock" or "silver hake" for collections made by the BCF during 1937–38 on its vessel *Brown Bear* mostly in the Aleutians, and *Merluccius productus* is not mentioned (Scheffer, 1959). This might explain some of the occurrences of "hake" on the original data sheets but not those where hake and pollock co-occurred in the same hauls, such as in the 1957 *Tordenskjold* exploration and the 1961 *Paragon* survey. The 1961 cruise plan even mentioned hake and pollock separately by scientific name.

Among contemporary (1955–61) BCF high seas salmon research cruises, Larkins (1964) mentions hake among numerous other bycatch species, including pollock, occasionally caught in surface gill-nets south of lat. 60° in the Bering Sea. An examination of several original records from these cruises, stored at the University of Washington, found bycatch mentioned as "whiting" and "silver hake" but without scientific names. There is no record of a catch of Pacific hake ever occurring in the Bering Sea among over 200 cruises within RACEBASE dating back to 1959 and nearly all records of hake are from

[5]Orsi, J., and B. Heard. 2008. "The *John N. Cobb* leaves a rich legacy." Alaska Fisheries Science Center Quarterly Report April–May–June 2008, p. 10–12.

hauls off British Columbia or the U.S. West Coast.

Aside from the records of hake from the 1957 *Tordenskjold* exploratory survey in the Shumagins, the next nearest record in RACEBASE is about 45 km south of the Shumagins, from the 2007 Gulf of Alaska bottom trawl survey. Additionally, two hake were caught and photographed (but not retained) near Kiska Island about 1,300 km west of the Shumagin Islands hake sites (Fig. 15) during the NMFS 2006 Aleutian Islands bottom trawl survey (Rooper, 2008).

Alaska fish guide books also have several contradictions about the occurrence of hake in the Bering Sea. The northern distribution of hake in Mecklenburg et al. (2002) is based primarily on Allen and Smith (1988), who based their northern distribution on the 1953–83 trawl surveys in AFSC's RACEBASE. Thus, both of these publications would have included the *Tordenskjold* 1957 Shumagin survey. The distribution maps of Allen and Smith (1988) and Mecklenburg et al. (2002) match well with that cruise but neither show any hake occurrence in the Bering Sea. Additionally, Mecklenburg et al. (2002) discounted the assertions of Fedorov (1973), who listed hake as a Bering Sea slope species, because there were no other Bering Sea references for hake, but Mecklenburg et al. (2002) did not mention the high-seas gillnet catches from the Bering Sea (Larkins, 1964). Mecklenburg et al. (2002) note that there was a single hake caught in Casco Cove at Attu Island in 1964 which is stored at the University of British Columbia fish collection (catalog number UBC 65-0005, collector is Peden), but which has no collection information.

Wilimovsky (1964) is probably the source of this hake, as he collected fish throughout the Aleutians by chemically treating tide pools, but does not mention hake among the most common specimens caught, nor does he specify the dates of his collections. However, he did sample at Attu and he thanks A. E. Peden as a field activity participant.

Older fish guide books, such as Kessler's (1985) guide to Alaska marine fish based on AFSC trawl surveys and

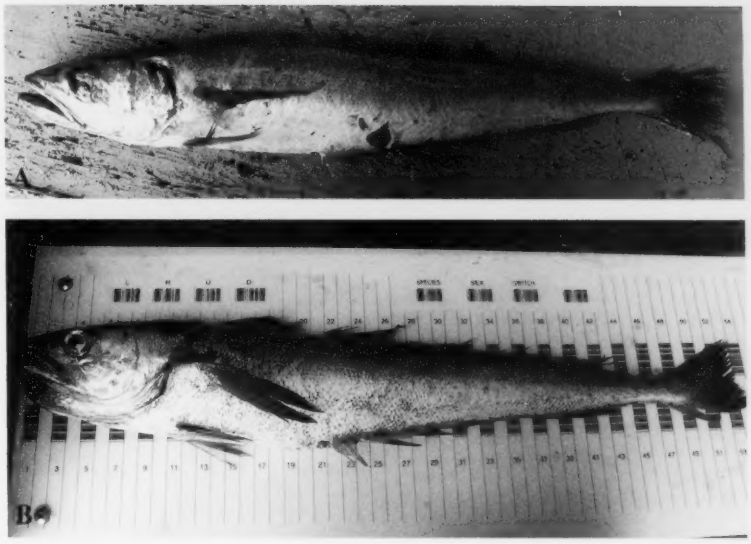

Figure 15.—Pacific hake, *Merluccius productus*, caught near Kiska Island by the *Sea Storm* in hauls 97 (A) and 186 (B) during the Alaska Fisheries Science Center's 2006 Aleutian Islands bottom trawl survey. Photos courtesy of Gulf of Alaska and Aleutian Islands bottom trawl survey staff.

Japanese guides based on their commercial fisheries in the Bering Sea (Okada and Kobayashi, 1968) and in the southwestern Bering Sea and Bristol Bay (Kobayashi and Ueno, 1956), do not mention hake. In his review on the world-wide distribution of *Merluccius* species, Hart (1947) shows hake extending into the Bristol Bay and Norton Sound portions of the Bering Sea, which was based on the northern limit of northwestern Alaska in Clemens and Wilby (1946). However, Clemens and Wilby retracted the northern boundary back to the Gulf of Alaska in a later edition (1961).

Thus, with all the contradictory evidence it seems difficult to state unequivocally whether or not hake were a part of the southern Bering Sea ecosystem in the 1950's and 1960's. I postulate (lead author M.Z.) that there was a small, self-sustaining stock in the southern Bering Sea and Shumagin area, perhaps migrating seasonally between these two areas, and that this stock was decimated by fishing or a regime shift, such that it is now fully or nearly extinct. Northern hake stragglers, such as those caught in NMFS bottom trawl survey tows in 2007 in the Gulf of Alaska and in 2006 in the Aleutian Islands, might be from remnants of this population or from more southern populations (Iwamoto et al., 2004).

Red King Crab

The abundance of red king crab in the Gulf of Alaska and the southeast Bering Sea has been greatly reduced since the 1940's. The Unimak broodstock of red king crab is now gone, replaced by a bottom trawl fishery for Pacific cod (Dew and McConnaughey, 2005). Pavlof Bay was made famous by Anderson and Piatt (1999) as an example of large-scale species shifts due to changing environmental conditions (regime shift), as recorded in a Gulf of Alaska small-mesh shrimp survey which started in 1972. Data from Anderson and Piatt (1999) show Gulf of Alaska red king crab peaking in abundance in the late 1970's and then crashing in the mid-1980's.

Today the former abundance of red king crab and the nursery status of Canoe Bay, which was discovered

during the 1940–41 expedition (FWS, 1942) and confirmed in 1948 by the *Pacific Explorer* fleet (Wigutoff and Carlson, 1950) and the *Washington* (Ellson et al., 1949), is forgotten. Indeed, neither Canoe Bay nor reports from these exploratory cruises are mentioned in Anderson and Piatt (1999). Perhaps the king crab stock in Canoe Bay has persisted even while the Pavlof Bay stock has disappeared.

Bans on the primarily foreign but conservative (FWS, 1942; Wigutoff and Carlson, 1950; INPFC, 1959) tangle nets (1954) and trawls (1960) to fish for red king crab in Alaska waters (Blackford, 1979) have not been adequate to preserve historical abundance levels. In Bristol Bay, the commercial pot harvest increased from 4 million kg in 1970 to an all-time record of 60 million kg in 1980, the same year that commercial fish trawling in the nearshore broodstock habitat began in earnest (Dew and McConnaughey, 2005). Thus, after an 11-year (1970–80) harvest increase of more than 1,000%, the population collapsed precipitously in 1981 and the Bristol Bay red king crab fishery was closed for the 1983 season and remains low to this day (NPFMC, 2007). Remnants of the historical red king crab aggregations, such as a 951 kg ($n = 332$) red king crab catch on the *Aldebaran* in 2003, the largest over an 8-year span (1995–2003), are still sometimes encountered in the Bering Sea bottom trawl survey (Fig. 16).

Figure 16.—The largest catch of red king crabs (951 kg, 332 crabs) from the Alaska Fisheries Science Center's Bering Sea bottom trawl survey in 2003, caught on the charter vessel *Aldebaran*. Pictured from left to right are Ivan Loyola (International Pacific Halibut Commission), John Brogan (Resource Ecology and Fisheries Management Division, AFSC), Brian Mason (Fisheries Monitoring and Analysis Division, AFSC), Gary Mundell (Resource Assessment and Conservation Engineering Division, AFSC), and Mike Burger (crew member of the *Aldebaran*). Other scientists participating in this cruise were Peter Cummiskey (Kodiak Laboratory, AFSC) and Terry Sample (Resource Assessment and Conservation Engineering Division, AFSC), who was probably the photographer.

Because the Bristol Bay (EBS) and Kodiak (GOA) red king crab fisheries were both closed in 1983, it is generally assumed that the timing of the population collapses was similar over a large geographical range encompassing the EBS and the GOA; however, exploitation histories and stock trajectories are quite different for the two areas (Zheng et al., 1996; Orensanz et al., 1998). The Kodiak-area red king crab fishery became firmly established in 1950 and the commercial catch peaked in 1965 at 40 million kg (Jackson and Manthey, 1969), some 14 years earlier than the 1980 Bristol Bay peak. The Kodiak-area catch then declined by about 78% over the next three seasons and stabilized at 8–10 million kg for the next 10–12 years, sustained only by a 4-fold increase in fishing effort during this time.

In the spring of 1967 the high proportion of unmated, new-shell females (58%) and the low proportion of males in the spawning population (<10%) signaled that the breeding-size males were being overharvested (McMullen, 1967; 1968). From 1971–73 to 1982 the rate of exploitation of Kodiak legal-male red king crab increased from about 20% to 70% (Orensanz et al., 1998), and there has been no Kodiak (GOA) commercial season since 1983.

The collapse of the Bristol Bay stock was more spectacular than the Kodiak decline, falling from a greater height (60 million kg vs. 40 million kg) in a shorter time (2–3 years vs. 17–18 years). However, similar to the demise of Kodiak's fishery, the collapse of the Bristol Bay stock was accompanied by historically high exploitation rates and depressed sex ratios (Dew and McConnaughey, 2005). Both the Kodiak and the Bristol Bay fisheries exhibited hallmark symptoms of overfishing not easily mistaken as natural mortality from environmental or ecological perturbations. Moreover, it is unlikely that a 1976–77 meteorological regime (Benson and Trites, 2002) shift could be a factor common to distinctly separate population collapses that occurred in 1965–68 (Kodiak) and 1980–83 (Bristol Bay). Regardless of the causes of these declines, the era of red king crab dominance, which inspired these 1940–60's surveys and commercial fisheries, is over for the foreseeable future.

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Overview of the U.S. East Coast Bottom Longline Shark Fishery, 1994–2003

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Introduction

Shark exploitation in the U.S. Atlantic and Gulf of Mexico, sporadic throughout much of the twentieth century, has greatly increased over the last three decades. Shark stock assessments (NMFS[1, 2, 3]) have varied in their estimates of stock size, fishing mortality, and maximum sustainable yield (MSY). However, each assessment reached the same general conclusion: shark mortality from a combination of fishing efforts has exceeded the reproductive capacity of certain species to the detriment of overall stock size. These conclusions are corroborated by substantial declines in shark catch-per-unit-effort (CPUE) in commercial fishery samples, fishery-independent longline fishing experiments (NMFS[1, 2, 3]), and recreational fishing tournament data (Hueter[4]).

Sharks are argued to be highly susceptible to overfishing because of their *K*-selected life history characteristics (Heppell et al., 1999; Cortés, 1999, 2002). Many of the species important to commercial and recreational fisheries grow slowly, mature at larger sizes, and have limited reproductive capacity. Given the biological constraints on shark production, the intensive fishing of shark resources is believed to be unsustainable.

Various management agencies examined strategies for sustainable utilization of the resource in the early 1990's. Initially, Texas, North Carolina, Virginia, and Florida enacted regulations for shark fisheries within their state waters (NMFS[5]). A Federal Shark Fishery Management Plan (FMP) was implemented in 1993 by the National Marine Fisheries Service (NMFS) for 39 species in the U.S. Atlantic and Gulf of Mexico waters (NMFS[5]). Implementation of this plan, in development for nearly a decade, was hampered by a lack of adequate data.

Initial regulations in the FMP included seasonal commercial quotas, recreational bag limits, and prohibitions of "finning" and recreational catch sales which were all designed to enhance stock rebuilding. The FMP proposed a data collection plan, including utilization of at-sea observers to verify logbook information and gather pertinent data on shark discards and interactions with protected and endangered resources. Subsequent FMP modifications were implemented reflecting results of updated assessments and newly generated biological data (NMFS[6,7,8]).

[1]NMFS. 1994. Report of the shark evaluation workshop. March 1994. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Southeast Fish. Sci. Cent., Miami, Fla., 46 p.

[2]NMFS. 1998 report of the shark evaluation workshop. June 1998. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Southeast Fish. Sci. Cent., Miami, Fla., 109 p.

[3]NMFS. 2006. SEDAR 11 stock assessment report: Large coastal shark complex, blacktip and sandbar shark. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Silver Spring, MD 20910, 387 p.

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[4]Hueter, R. E. 1991. Survey of the Florida recreational shark fishery utilizing shark tournament and selected longline data. Final report, Fla. Dep. Nat. Resour., Grant Agreement 6627, 74 p.

[5]NMFS. 1993. Fishery management plan for sharks of the Atlantic Ocean. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., 273 p.

[6, 7, 8]*See next page.*

ABSTRACT—The U.S. Atlantic coast and Gulf of Mexico commercial shark fisheries have greatly expanded over the last 30 years, yet fishery managers still lack much of the key information required to accurately assess many shark stocks. Fishery observer programs are one tool that can be utilized to acquire this information. The Commercial Shark Fishery Observer Program monitors the U.S. Atlantic coast and Gulf of Mexico commercial bottom longline (BLL) large coastal shark fishery. Data gathered by observers were summarized for the 10-year period, 1994 to 2003. A total of 1,165 BLL sets were observed aboard 96 vessels, with observers spending a total of 1,509 days at sea. Observers recorded data regarding the fishing gear and methods used, species composition, disposition of the catch, mortality rates, catch per unit of effort (sharks per 10,000 hook hours), and bycatch of this fishery. Fishing practices, species composition, and bycatch varied between regions, while catch rates, mortality rates, and catch disposition varied greatly between species.

An onboard observer program is an effective means of rapidly gathering detailed information on: 1) species and size composition of the catch and landings, 2) catch-per-unit-effort (CPUE) (number of sharks caught per 10,000 hook hours), and 3) disposition (released alive, discarded dead, used for bait, etc.) of nonlanded catch. An observer program garners details otherwise not captured by mandatory vessel logbook data, and it simultaneously "ground truths" this information.

In 1994, the Commercial Shark Fishery Observer Program (CSFOP) initiated monitoring of bottom longline (BLL) vessels targeting sharks in the U.S. Atlantic and Gulf of Mexico; the principle U.S. directed commercial fishery for large coastal sharks. The CSFOP has generated one of the most extensive and detailed biological databases in existence for sharks of the western North Atlantic.

The FMP allocated northwest Atlantic shark species into five groupings for potential management purposes. The "large coastal" (LC) shark complex represents an assemblage of 11 species of carcharhinid, sphyrnid, and orectolobid sharks (Table 1), which have historically been the target of the BLL fishery and have been managed as a unit. The "small coastal" (SC) shark complex, another managed complex of three carcharhinids and one sphyrnid species (Table 1), are less frequently targeted by BLL fishermen but are commonly captured as bycatch within the LC-targeted fishery and inshore gillnet, trawl, and hook fisheries. "Prohibited sharks" (PH) are a diverse group of 19 sharks (odontaspid, carcharhinid, and lamnoid sharks) deemed especially vulnerable and banned from landing (Table 1). "Pelagic sharks" (PE) (five lamnoid and carcharhinid sharks) and "dogfish" ((DF) excluded from management through the FMP) (Table 1) are infrequently taken in the BLL fishery (NMFS[9]). This paper characterizes the BLL shark fishery as monitored by the CSFOP in Atlantic waters of the United States from 1994 through 2003.

Materials and Methods

CSFOP observers were trained in the following areas: marine safety, sea turtle handling and resuscitation techniques, fishery and biological data collection, biological sampling, and shark and bycatch species identification. Observers were required to record catch and effort information from each longline set targeting coastal sharks during each sampled trip (a "trip" is defined as the time period between a fishing vessel's departure from port and its return to port with all deployed fishing gear fully retrieved). Data and biological samples were returned to the Florida Museum of Natural History (FLMNH) at the University of Florida for processing and further studies. Data were archived and analyzed using a customized Microsoft Access database.[10] Relevant specimens and biological samples were archived at FLMNH for further study.

Fishing vessel participation in the CSFOP was voluntary from 1994 to 2001. CSFOP personnel (Principal Investigators or observers) personally solicited individual longline vessel owners and/or captains for permission to monitor their fishing trips. Due to the voluntary nature of the program at this time, monitoring was nonrandom by nature and certain vessels were observed repetitively, particularly during the latter part of this period. Percent observer coverage was calculated by dividing the total number of LC sharks landed on observed trips by the total number of commercially landed LC sharks during the same time period according to National Marine Fisheries Service (NMFS) records (Cortes and Neer[11]). Sampled trips were responsible for approximately two percent of total recorded commercial landings.

As NMFS regulatory measures were enacted and implemented, it became increasingly difficult to identify vessels willing to voluntarily accept observers (Burgess[12]). Placement of observers was made mandatory by NMFS in 2002. Vessels were selected by NMFS from a pool developed after consulting data generated by mandatory NMFS landing logbooks (Rilling[13]). Vessels identified as actively landing sharks were matched with vessels holding valid Federal shark permits for the upcoming fishing season. Those vessels that documented sharks as more than 25% of their total landings from the same fishing season of the previous year were deemed eligible for selection. A pseudo-random number generator was used to select vessels within three subregions (Mid-Atlantic Bight, southeastern U.S. Atlantic, and Gulf of Mexico). The number of vessels selected for monitoring in a given season was based on the number of fishing days projected by NMFS for the fishery in that season.

Owners/captains of selected vessels were required to contact the observer coordinator at least 48 hr prior to departing port on any trip where LC sharks were targeted or caught incidentally using BLL fishing gear. Individual observers were then deployed to vessels by the observer coordinator. To carry an observer, the vessels were

[6]NMFS. 1993. Secretarial shark fishery management plan for the Atlantic Ocean. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., var. pagin.

[7]NMFS. 2003. Final Amendment 1 to the fishery management plan for Atlantic tunas, swordfish and sharks. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., var. pagin.

[8]NMFS. 2006. Final consolidated Atlantic highly migratory species Fishery Management Plan. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., var. pagin.

[9]NMFS. 2006. Final Consolidated Atlantic Highly Migratory Species Fishery Management Plan. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Office of Sustainable Fish., Highly Migratory Species Manage. Div., Silver Spring, Md., 1,600 p.

[10]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[11]Cortés, E., and J. A. Neer. 2002. Updated catches of sharks. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, SEFSC Panama City Lab. Doc. SB/02/15 of the 2002 Shark Evaluation Workshop. Panama City, Fla., June 24–28, 2002, 62 p.

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[13]Rilling, Chris. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Sustainable Fisheries Division, Highly Migratory Species, Silver Spring, Md. 20910. Personal commun.

Table 1.—Number of each shark species, categorized into their respective management units, observed caught in each of the three regions ((EGM = Eastern Gulf of Mexico, MAB = Mid Atlantic Bight, and SE US = Southeastern U.S. Atlantic), and the percentage of the total catch and management unit catch each species represented. "T" designates trace amounts (<0.01%).

Region and species	No. caught					
	EGM	MAB	SE US	Total	Percent of total	Percent mgt category
Large coastal						
Sandbar, *Carcharhinus plumbeus*	4,277	11,463	4,048	19,788	35.9	56.7
Tiger, *Galeocerdo cuvier*	945	1,789	2,873	5,607	10.2	16.1
Blacktip, *Carcharhinus limbatus*	3,087	355	1,586	5,028	9.1	14.4
Nurse, *Ginglymostoma cirratum*	846	7	302	1,155	2.1	3.3
Scalloped hammerhead, *Sphyrna lewini*	411	199	222	832	1.5	2.4
Bull, *Carcharhinus leucas*	564	45	70	679	1.2	1.9
Spinner, *Carcharhinus brevipinna*	432	34	102	568	1.0	1.6
Silky, *Carcharhinus falciformis*	282	8	199	489	0.9	1.4
Great hammerhead, *Sphyrna mokarran*	253	34	106	393	0.7	1.1
Lemon, *Negaprion brevirostris*	334	11	29	374	0.7	1.1
Smooth hammerhead, *Sphyrna zygaena*	0	0	6	6	T	T
Subtotal	11,431	13,945	9,543	34,919	63.4	100.0
Small coastal						
Atlantic sharpnose, *Rhizoprionodon terraenovae*	2,123	2,236	10,501	14,860	27.0	85.9
Blacknose, *Carcharhinus acronotus*	1,332	38	997	2,367	4.3	13.7
Bonnethead, *Sphyrna tiburo*	15	0	52	67	0.1	0.4
Finetooth, *Carcharhinus isodon*	2	1	6	9	T	0.1
Subtotal	3,472	2,275	11,556	17,303	31.4	100.0
Prohibited						
Dusky, *Carcharhinus obscurus*	41	1,440	170	1,651	3.0	76.6
Sandtiger, *Carcharias taurus*	0	342	26	368	0.7	17.1
Night, *Carcharhinus signatus*	41	0	8	49	0.1	2.3
Bignose, *Carcharhinus altimus*	13	11	5	29	0.1	1.3
White, *Carcharodon carcharias*	2	1	13	16	T	0.7
Caribbean reef, *Carcharhinus perezii*	10	3	2	15	T	0.7
Sixgill, *Hexanchus griseus*	7	0	1	8	T	0.4
Bigeye thresher, *Alopias superciliosus*	2	0	4	6	T	0.3
Sevengill, *Heptranchias perlo*	6	0	0	6	T	0.3
Bigeye sixgill, *Hexanchus nakamurai*	3	0	0	3	T	0.1
Galapagos, *Carcharhinus galapagensis*	0	0	2	2	T	0.1
Angel, *Squantina dumeriil*	0	1	0	1	T	0.0
Subtotal	125	1,798	231	2,154	3.9	100.0
Dogfish						
Smooth dogfish, *Mustelus canis*	195	375	73	643	1.2	93.7
Florida smoothhound, *Mustelus norrisi*	29	0	2	31	0.1	4.5
Roughskin spiny dogfish, *Cirrhigaleus asper*	6	0	0	6	T	0.9
Spiny dogfish, *Squalus acanthias*	0	1	5	6	T	0.9
Subtotal	230	376	80	686	1.2	100.0
Pelagic						
Shortfin mako, *Isurus oxyrinchus*	1	6	2	9	T	50.0
Common thresher, *Alopias vulpinus*	0	1	8	9	T	50.0
Blue, *Prionace glauca*	0	0	0	0	T	0.0
Subtotal	1	7	10	18	T	100.0
Grand total	15,259	18,401	21,420	55,080	100.0	

required to have a Commercial Fishing Vessel Safety Decal (CFVSD), issued by the U.S. Coast Guard, and be capable of providing room and board for the observer that was equivalent to that given to the crew. In addition to these NMFS mandated requirements, the CSFOP did not deploy observers aboard vessels smaller than 30 ft in length (because of space and safety considerations), vessels operated by a captain or crew known to abuse alcohol or drugs at sea, or other safety issues reported by observers and documented by the CSFOP.

When deployed on BLL vessels, observers recorded specific details regarding the fishing gear utilized and associated catch during each set for the duration of the trip. The term "set" refers to an individual BLL set, which includes the deployment and retrieval of fishing gear and associated catch. Recorded were the size and number of hooks, time and latitude and longitude coordinates when the first and last hooks entered and were removed from the water, bait utilized, and length of the deployed mainline. For analytical purposes, we divided the sampled area into three geographical subregions for our analysis: the Mid Atlantic Bight (MAB), the Atlantic coast of the southeastern U.S. (SE US), and the eastern Gulf of Mexico (EGM). The boundaries of these regions and the locations of observed BLL sets are identified in Figure 1.

Vessel captains calculated and provided the length of the mainline from their Global Positioning System (GPS) readings. GPS or Loran geographic positions were recorded. Loran coordinates were converted to latitude/longitude using the Coast Guard POSAID2 version 2.1a computer program. Water depth at

the location of each set was measured with sonar, and bottom water temperature was recorded by a Stowaway XTI temperature recorder[14] fastened to one end of the longline. Air and sea surface water temperatures were recorded using a glass-stem thermometer.

Soak time was defined as the temporal interval between entry of the first hook and removal of the first hook from the water. CPUE for each set was calculated as the number of sharks caught per 10,000 hook hours (CPUE = catch × 10,000/(hooks x soak time)). CPUE calculations do not include or adjust for hook type and size, type of bait used, distance between hooks, gangion length and material (monofilament, steel), or the specific sharks targeted (SC or LC, sandbar or blacktip).

All catch was identified to the lowest possible taxon, and disposition of it was recorded. Disposition categories included: landed, used for bait, released alive, discarded dead, tagged (with a NMFS M-style dart tag), released, archived as museum specimens, or another category. To determine at-vessel mortality rates observers recorded the condition (alive or dead) of hooked animals when brought on board. Animals were deemed alive if there was any response to tactile stimuli (there were no varying degrees of alive) and dead if there was no response. Straight-line total (TL) and fork (FL) length measurements, to the nearest cm, were recorded for all sharks brought on board. For bycatch, TL was measured for fish, disc width (DW) for batoids, carapace length and width for sea turtles, and TL was estimated for cetaceans. The sex of elasmobranchs was noted and clasper lengths were measured to the nearest mm.

[14]Onset Computer Corporation, 470 MacArthur Blvd., Bourne, MA 02532.

Results

Observer Coverage

The geographic region sampled ranged from New Jersey to Louisiana. A total of 229 shark sets in the MAB, 507 sets in the SE US, and 403 sets in the EGM were observed during the study period (Fig. 1). Within each subregion there were core areas of highly observed fishing effort, namely waters off Cape Hatteras, NC (MAB), the waters off Daytona, Fla. (SE US), and waters north of the Florida Keys (EGM). The concentration of samples in these areas was, to some degree, due to increased utilization of these areas by participating vessels during the voluntary time period (1994–2001).

During 1994–2003, 434 trips were sampled including 1,165 BLL sets and 1,509 sea days aboard 96 vessels (Table 2). During the years that participation was voluntary, trips of 1–7 vessels per season were sampled. The percentage of landings sampled was extremely limited at times, due to insufficient funding. The least number of vessels observed (one in the winter and two in the summer) occurred during 2000, when funding restrictions limited observation to only the SE US region (Table 2). The greatest number of vessels observed (six in the winter and seven in the summer) occurred during 1995, the second year of the voluntary program (Table 2). There was a significant difference in the seasonal numbers of vessels observed in the voluntary 1994–2001 and mandatory 2002–03 periods (Table 2). The shift to mandatory observers resulted in increased seasonal totals of 9 (winter 2002), 10 (summer 2003), and 15 vessels (winter 2003) (Table 2).

Sampled trips caught 0.6–3.8% of large coastal shark commercial landings during 1994–2003 (Table 3). Sampled trips included only 0.6% of the landed catch during 2000 but 3.8% in 2003 (Table 3). On average, sampled trips observed 1.9% of the landed catch during the study period (Table 3).

Observers spent between 22 and 166 days at sea per fishing season during 1994–2003, most of it during the winter seasons (n=850 all years combined), compared to the summer seasons (659 all years combined) (Table 2). The highest and lowest numbers of days at sea occurred during the 2003 (166 sea days) and the 2000 (22 sea days) winter fishing seasons, respectively (Table 2). Days at

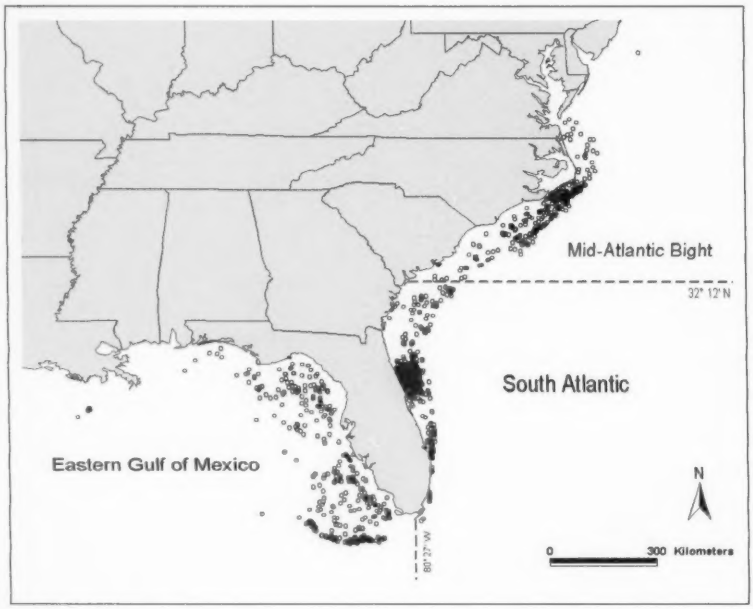

Figure 1.—The southeastern coast of the United States and the Gulf of Mexico with points representing individual BLL sets observed in each of the three regions (Mid Atlantic Bight, Southeastern U.S. Atlantic, and Gulf of Mexico). The solid line indicates the 100 m bathymetric contour.

sea per season were similar between voluntary and mandatory coverage periods (Table 2), and variations in days at sea were due to funding, vessel availability, meteorological and oceanographic sea conditions, and the seasonal abundance of the target species.

The number of trips observed varied greatly depending on the species targeted, shark abundance, and the length of the legal open season. The number of trips per season was similar during the voluntary (6–40) and mandatory years (15–42) of the program (Table 2). The lowest number of trips (7 in the summer and 6 in the winter) were observed during 2000 (coinciding with a reduction in funding) and the largest number of trips were observed in 2002 summer (n=42) and 2003 winter seasons (n=42) (Table 2).

The total number of BLL sets observed per season ranged from 21–88 during the voluntary period and 37–102 during the mandatory period (Table 2). The highest number of sets was observed during the mandatory 2003 winter season (n=102), while the lowest number of sets occurred during the voluntary 1997 and 2001 summer, and 2000 winter seasons (n=21) (Table 2).

Table 2.—Total number of vessels, longline sets, trips, and sea days observed during each year of the Commercial Shark Fishery Observer Program (CSFOP).

			Winter			Summer		
Year	Vessels (winter)	Vessels (summer)	No. of trips	No. of sets	No. of sea days	No. of trips	No. of sets	No. of sea days
1994	4	5	15	52	69	16	49	70
1995	6	7	40	87	110	24	88	103
1996	7	5	28	79	101	12	44	52
1997	4	5	24	66	73	12	21	33
1998	6	4	37	85	104	10	26	32
1999	4	4	18	51	51	21	56	71
2000	1	2	7	21	22	6	39	24
2001	4	3	31	63	95	11	21	30
2002	9	15	15	37	59	42	101	147
2003	15	10	42	102	166	23	77	97
Total	60	60	257	643	850	177	522	659

Fishing Practices and Gear

Sixteen sizes of hooks were sampled during the duration of the study. Both circle and "J" style hooks were used but are not differentiated here because this information was not routinely collected during the duration of the study. More than one size of hook was frequently employed in individual sets; however, size 14/0 hooks were most commonly utilized in 6 out of 10 years (Table 4). In the other four years they were the second most frequently used after size 18/0 hooks (Table 4). Size 14/0 hooks were used in 86.1–94.2% of sets made during 1994–97 (Table 4). By contrast, during the 1999–2003 fishing seasons, 14/0 hooks were only used in 25.0–45.5% of sets, and were replaced by larger 18/0 hooks (Table 4). Size 3/0 and 3.5/0 hooks were also commonly used, most often for sets targeting SC sharks (Table 4).

There were regional preferences in the sizes of hooks used. In the MAB, 14/0 hooks and 3/0 hooks were used in 96.2% and 36.5% of the sets, respectively (Table 5). Fishermen in the EGM used 14/0 hooks on the majority (56.3%) of sets, while in the SE US fishermen used 18/0 hooks and 14/0 hooks in 37.0% and 26.6% of sets, respectively (Table 5). Data from the last year of the study provided the greatest range in size of hooks used in the fishery (Table 4).

The mean number of hooks used during individual sets annually ranged from 350 to 844, with a minimum of 53 and a maximum of 2,385 hooks recorded across all sets (Table 4). A greater number of hooks were used per set during 1994–97 than between 1998 and 2003 (Table 4). On average, twice as many hooks were used in sets in the EGM (mean = 843) compared to the MAB (mean = 412) (Table 5). The low number of hooks used in the year 2000 (mean = 350) is likely an artifact of reduced observer coverage (Table 4).

The majority of fishermen used monofilament mainline instead of steel cable. Mainline length deployed per set ranged from 1 to 24 nmi (1.9–44.5 km), but the most commonly used length was between 5 and 8 nmi (9.3–14.8 km) (n=447) (Fig. 2). Sets greater than 17 nmi (31.5 km) in length were rare (n=14) (Fig. 2). Analysis of yearly trends in the length of gear indicate that 8–12 nmi (14.8–22.2 km) of gear was commonly used during the early years

Table 3.—Total number of large coastal sharks observed caught in each of the three regions by the CSFOP, total number of commercial landings (Cortes and Neer[1]), and the total percent of large coastal shark catch observed by the CSFOP between 1994 and 2003.

	No. of sharks									
Area/Item	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Southeastern U.S. Atlantic (CSFOP observed)	149	1,022	677	335	386	843	658	477	896	987
Eastern Gulf of Mexico (CSFOP observed)	698	810	503	403	806	552	0	825	1,516	2,805
Mid Atlantic Bight (CSFOP observed)	1,275	1,893	1,507	1,063	2,634	979	0	1,815	517	885
Total (CSFOP observed)	2,122	3,725	2,687	1,801	3,826	2,374	658	3,117	2,929	4,677
NMFS total	228,000	222,400	160,600	130,600	174,900	111,500	111,200	95,700	123,400	122,100
Percent observed CSFOP	0.9%	1.7%	1.7%	1.4%	2.2%	2.1%	0.6%	3.3%	2.4%	3.8%

Overall average observer coverage = 1.9%

[1]Cortés, E., and J. Neer. 2005. Updated catches of sharks. NOAA Fisheries, SEFSC, Panama City Lab. Doc. LC05/06-DW-16 of the 2005 Shark Evaluation Workshop. Panama City, Fla., Oct. 31–Nov. 4, 2005, 112 p.

Table 4.—Percentage of hook sizes observed used per year and the average, minimum, and maximum number of hooks observed used on individual sets during each year. Multiple hooks were sometimes used on an individual set; therefore, percentages can be over 100.

	Percentage of hooks observed									
Hook size	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
3/0	36.6	16.5	18.8	22.4	1.0	0.0	0.0	0.0	12.5	7.9
3.5/0	15.8	23.7	2.9	0.0	0.0	0.0	0.0	0.0	4.4	5.6
4/0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
5/0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
6/0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.7
8/0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0
9/0	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10/0	0.0	4.1	0.0	0.0	2.0	0.0	0.0	0.0	1.5	6.2
12/0	0.0	1.0	0.0	37.9	0.0	0.0	0.0	0.0	8.1	11.8
13/0	0.0	0.0	0.0	3.4	15.0	2.0	15.6	0.0	0.0	7.9
14/0	86.1	93.8	94.2	89.7	0.0	45.5	31.3	42.9	25.0	33.1
15/0	0.0	0.0	0.0	0.0	5.0	10.1	0.0	7.8	0.0	0.0
16/0	0.0	0.0	0.0	3.4	25.0	1.0	0.0	0.0	11.0	21.3
17/0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0
18/0	0.0	0.0	0.0	5.2	33.0	41.4	57.8	50.6	26.5	6.2
20/0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	14.6
Average no. of hooks	844	825	755	653	577	508	350	594	484	587
Minimum no. of hooks	53	284	160	66	69	102	90	75	69	54
Maximum no. of hooks	1,181	1,218	1,054	1,142	1,154	1,153	538	1,080	1,250	2,385

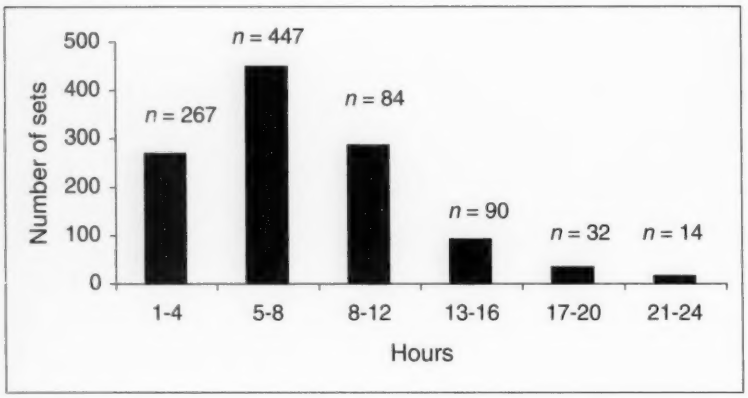

Figure 2.—Numbers of individual BLL sets observed by soak time.

(1994–96), while 1–4 nmi (1.9–7.4 km) of gear was more commonly used in the later years (1999–2003) (Fig. 3). This reduction in length is most likely due to the implementation of trip limits in 1997 (NMFS[15]). Regional analysis shows that fishermen in both the EGM and SE US deployed 5–8 nmi (9.3–14.8 km) sets most frequently, followed by 9–12 nmi (16.7–22.2 km) in the EGM, and 1–4 nmi (1.9–7.4 km) in the SE US. In the MAB, sets of 9–12 nmi (14.8–22.2 km) were deployed most frequently, followed by 13–16 nmi (24.1–29.6 km) sets (Fig. 4).

Close to half of all sets (46.9%) had a soak time of 13–16 h in length. Soak times less than 13 h in length accounted for 38.1% of all sets and only 15.0% of all sets had a soak time greater than 16 h (Fig. 5). There were no regional differences in soak time.

The vast majority of all fishing effort (hook hours) occurred in water <50 m (75%), with peak effort (29.0%) in water 20–30 m deep (Fig. 6). Fishermen in the EGM and SE US set hooks in water >150 m in depth, while fishermen in the MAB only set to depths of 90 m. Fishing effort in the EGM was highest at depths of 10–20 m (19.5%) and at depths of 20–30 m for both the SE US (38.8%) and MAB (39.1%) regions (Fig. 7).

Table 5.—Percentage of hook sizes observed used in each of the three regions (EGM = Eastern Gulf of Mexico, MAB = Mid Atlantic Bight, and SE US = Southeastern U.S. Atlantic). Multiple sizes of hooks were used on some sets, therefore percentages do not always add up to 100.

	Percentage of hooks observed		
Hook size	EGM	MAB	SE US
3/0	5.0	36.5	3.8
3.5/0	0.0	11.8	9.0
4/0	0.0	0.0	0.0
5/0	0.0	0.0	0.3
6/0	1.0	0.0	0.0
8/0	1.3	0.0	0.0
9/0	0.0	12.3	0.0
10/0	0.0	0.0	5.2
12/0	8.0	2.4	4.9
13/0	2.0	1.9	11.2
14/0	56.3	96.2	26.6
15/0	6.5	0.0	0.0
16/0	13.0	0.9	4.7
17/0	0.0	0.0	0.0
18/0	16.3	0.5	37.0
20/0	0.0	0.0	10.4
Average no. of hooks	843	412	680
Minimum no. of hooks	53	54	75
Maximum no. of hooks	2,385	1,151	1,250

Catch Composition and Disposition

During the study period, a total of 55,080 individual sharks were captured

[15]NMFS. 1997. Framework seasonal adjustment of management measures under the fishery management plan for sharks final environmental assessment and regulatory impact review/final regulatory flexibility analysis. March 1997. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Office of Sustainable Fisheries, Silver Spring, Md.

during observed BLL sets (Table 1). These included 34 species from 10 families, with the family Carcharhinidae representing 93.5% of all sharks encountered. Divided into their respective management groups, the catch comprised of 34,919 LC sharks (11 species), 17,303 SC sharks (4 species), 2,154 PH species (12 species), 686 DF (4 species), and 18 PE sharks (3 species) (Table 1). The sandbar shark is the primary target species and represented 35.9% of the total catch (TC) in the fishery, and 56.7% of the LC management group (Table 1). The sandbar was followed by the Atlantic sharpnose (27.0% TC, 85.9% SC) (Table 1), an SC species. Other substantial LC shark species found in the catch included the tiger (10.2% TC, 16.1% LC) and blacktip (9.1% TC, 14.4% LC) (Table 1). The dusky shark, a PH species, represented 3.0% of the total catch and 76.6% of its management unit (Table 1). Smooth dogfish was the largest component of the DF management group (73.1%) and represented 1.2% of the total catch (Table 1). PE sharks, including the common thresher, shortfin mako, and blue, represented the remaining <0.1% of the TC (Table 1).

Species compositions varied between the three regions. No species dominated the catch in the EGM (n=15,259) (Table 1). The sandbar (28.0%), blacktip (20.2%), Atlantic sharpnose (13.9%), and blacknose (8.7%) sharks represented the four most commonly caught species in the EGM (Fig. 8).

In the SE U.S. region (n=21,420), the Atlantic sharpnose comprised almost half the TC (49.0%) (Fig. 8). The two most commonly targeted species, sandbar and blacktip, represented only 18.9% and 7.4% of the TC, respectively (Fig. 8). The tiger shark, which is commonly a non-target species, represented 13.4% of the TC in this region (Fig. 8). Twenty-nine species of sharks were caught in this region, the most of all three regions (Table 1).

Sandbar sharks dominated the catch in the MAB, representing 62.3% of the TC in that region (n=18,401) (Fig. 8). The Atlantic sharpnose (12.2%), tiger (9.7%), and dusky (7.8%) sharks repre-

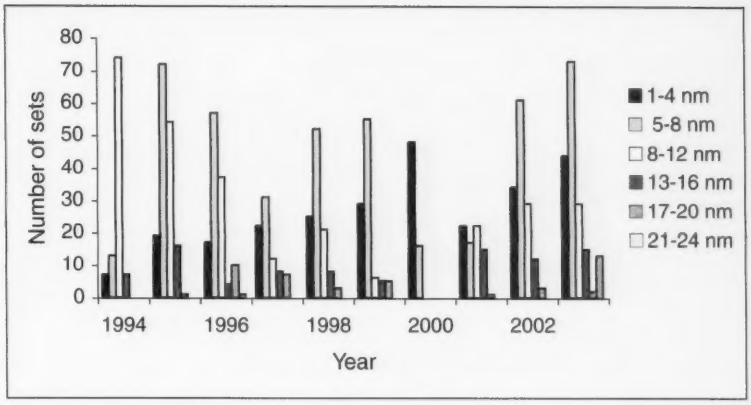

Figure 3.—Number of individual BLL sets observed per year by mainline length (nmi).

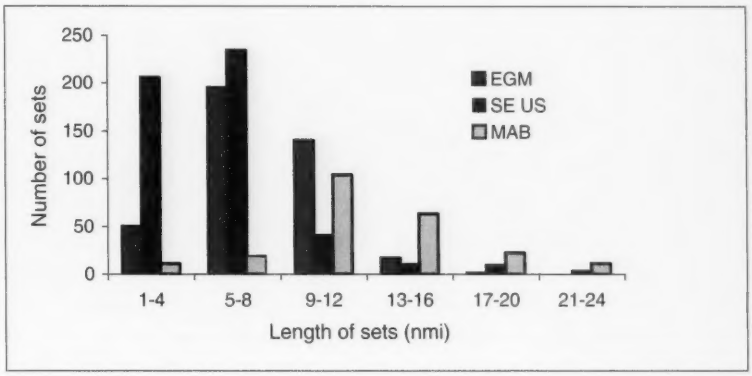

Figure 4.—Number of individual BLL sets observed in each of the three regions by mainline length (nmi).

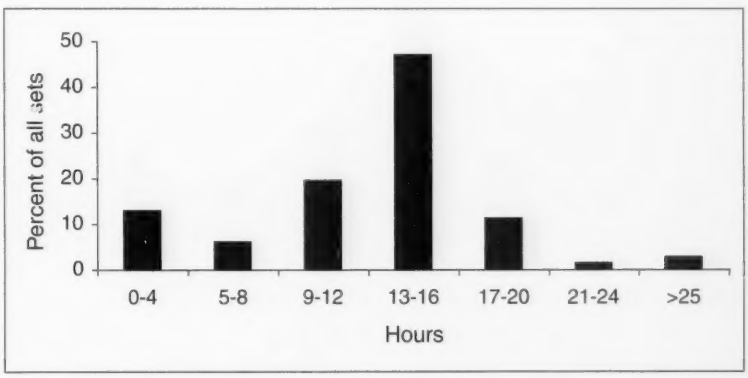

Figure 5.—Percent of all observed BLL sets by soak time.

sented the other most commonly caught species in this region (Fig. 8).

LC sharks caught on commercial BLL fishing gear had an 82.7% total mortality rate (Table 6). Total mortality includes sharks being landed, discarded dead, used for bait, or brought back to land for display or museum purposes. Seventy-five percent (75.9%) of all LC sharks were landed for commercial sale, 3.7% were discarded, 2.7% were used for bait, and 0.3% were used for display or museum specimens (Table 6). Of the 17.3% that survived the fishing process, 11.2% were released alive, 5.4% were tagged and released, and 0.7% were seen by an observer but escaped from the longline before being brought aboard (Table 6).

The sandbar and blacktip sharks were the most commonly targeted species in the fishery and were retained and landed 94.5% and 96.8% of the time, respectively (Table 7). The bull shark, although not traditionally targeted, was landed 94.6% of the time (Table 7). Sandbar, blacktip, and bull sharks suffered a total mortality rate of 95.4%, 99.6%, and 95.7%, respectively (Table 7). There were no yearly trends in disposition for any of these three species.

The dusky shark had total mortality rates ranging from 56.9–100% between 1994 and 2003 (Table 8). The average total mortality during the entire study period was 92.1% (Table 8). Regulations prohibiting the catch of dusky sharks in U.S. Federal waters went into effect in January 2001 (NMFS[16]). The total mortality rate for dusky sharks prior to 2001 was 94.1% and after 2001 was 78.2%. The dusky shark was most often retained and landed for sale during 1994–2001 (Table 7). Starting in 2002, shortly after being classified as a prohibited species, the majority of dusky sharks were discarded (Table 8).

The great hammerhead and scalloped hammerhead had very similar final dispositions. Both species had a total mortality rate >98.0%. For the great hammerhead, 62.3% were discarded, 26.5% were landed, 9.9% were used for bait, and 0.5% were retained for display or museum purposes, or had unknown disposition. For the scalloped hammerhead, 55.3% were discarded, 32.6% were landed, 9.9% were used for bait, and 0.6% were retained for display or museum purposes, or had unknown disposition (Table 7).

Tiger and nurse sharks were commonly caught nontarget species. Tiger shark disposition varied more than any other species in this fishery. They suffered a total mortality rate of only 30.9%, with 13.9% landed, 10.3% used for bait, 5.2% discarded, and 1.5% used for display, museum, or other purposes (Table 7). Of the 69.1% of tiger sharks caught alive, 42.8% were released, 25.4% were tagged, and 0.9% escaped (Table 7). Nurse sharks, rarely brought aboard or retained for sale, were released 95.8% of the time (Table 7).

SC sharks suffered 98.9% total mortality rate during the fishing process (Table 6). Over 60% of SC sharks (61.9%) were used for bait, 28.8% were landed for sale, 7.3% were discarded, and 1.0% were either retained for display or museum specimens (Table 6). SC sharks that survived the fishing process were either released (0.9%), tagged (0.2%), or escaped (0.1%) (Table 6).

Total mortality rates for Atlantic sharpnose were 96.3–100% during the entire study period (Table 8). There was a strong shift in the disposition of this species between the time periods 1994–97 and 1998–2003. During the first time period, Atlantic sharpnose sharks were landed most of the time (Table 8). After 1997, this species was landed very infrequently and was primarily used for bait (Table 8).

The blacknose shark, classified as an SC species, was commonly caught

Table 6.—Final disposition in number of individuals and percentages of large coastal (LC) and small coastal (SC) sharks observed caught during 1994–2003 and the total number and percent alive and dead for each category.

	LC		SC	
Disposition	No. of sharks	Percent	No. of sharks	Percent
Bait	941	2.7	10,710	61.9
Landed	26,483	75.9	4,986	28.8
Discard	1,290	3.7	1,255	7.3
Display	107	0.3	26	0.2
Museum	27	0.1	12	0.1
Other	30	0.1	116	0.7
Release	3,912	11.2	154	0.9
Tagged	1,869	5.4	30	0.2
Escape	254	0.7	12	0.1
Total	34,913	100.0	17,301	100.0
Alive	6,035	17.3	196	1.1
Dead	28,878	82.7	17,105	98.9

[16]NMFS. 1999. Final fishery management plan for Atlantic tunas, swordfish and sharks. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Office of Sustainable Fisheries, Highly Migratory Species Division, Silver Spring, Md., var. pagin.

Table 7.—Total number and percentage disposition by species for seven shark species during all years and regions combined.

	Great hammerhead		Scalloped hammerhead		Sandbar		Blacktip		Bull		Tiger		Blacknose	
Disposition	No.	%	No.	%	No.	%.	No.	%	No.	%.	No.	%	No.	%
Bait	39	9.9	82	9.9	20	0.1	58	1.2	0	0.0	576	10.3	433	18.3
Landed	104	26.5	271	32.6	18,698	94.5	4,863	96.8	642	94.6	782	13.9	1,473	62.2
Discard	245	62.3	460	55.3	129	0.7	68	1.4	6	0.9	289	5.2	334	14.1
Display	0	0.0	3	0.4	18	0.1	15	0.3	1	0.1	58	1.0	23	1.0
Escape	2	0.5	1	0.1	138	0.7	5	0.1	19	2.8	50	0.9	8	0.3
Museum	0	0.0	2	0.2	2	0.0	0	0.0	0	0.0	18	0.3	9	0.4
Other	2	0.5	0	0.0	11	0.1	2	0.0	1	0.1	9	0.2	4	0.2
Release	0	0.0	7	0.8	360	1.8	7	0.1	8	1.2	2,401	42.8	64	2.7
Tagged	1	0.3	6	0.7	412	2.1	8	0.2	2	0.3	1,424	25.4	19	0.8
Total	393	100.0	832	100.0	19,788	100.0	5,026	100.0	679	100.0	5,607	100.0	2,367	100.0
Alive	3	0.8	14	1.7	910	4.6	20	0.4	29	4.3	3,875	69.1	91	3.8
Dead	390	99.2	818	98.3	18,878	95.4	5,006	99.6	650	95.7	1,732	30.9	2,276	96.2

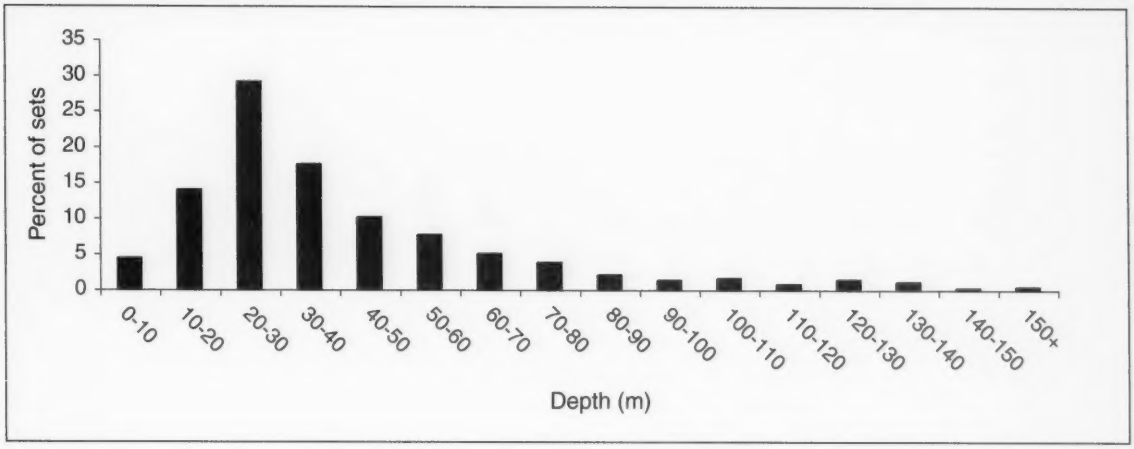

Figure 6.—Percent of all observed BLL sets by water depth.

and landed in this fishery. Of its 96.2% total fishing mortality rate, 62.2% were landed, 18.3% were used for bait, 14.1% were discarded, and 1.6% were retained for display, museum specimens, or other disposition (Table 7).

At-Vessel Mortality and CPUE

We analyzed at-vessel mortality data for information on species-specific viability relating to the stress of longline capture. The most tolerant species were the nurse (100% alive), tiger (93.3% alive), lemon (92.1% alive), bull (69.9% alive), and sandbar (66.6% alive) sharks. Less hardy species were the great hammerhead (4.2% alive), scalloped hammerhead (8.0% alive), silky (11.5% alive), and blacktip (13.9% alive) sharks (Fig. 9).

To determine whether soak time affected mortality rates, we quantified the percentage of dead sharks observed after soak times broken down into 4 h bins, ranging from 0 to >24 h. The majority of data supported the hypothesis that as soak time increased mortality rates increased. Sandbar sharks caught during sets with <4 h soak times had a low mortality rate of 6.5% (Table 9). This doubled to 12.7% during soak times of 4–8 h and increased to a peak of 51.3% during soak times of 20–24 h (Table 9). Atlantic sharpnose and blacknose sharks showed large increases

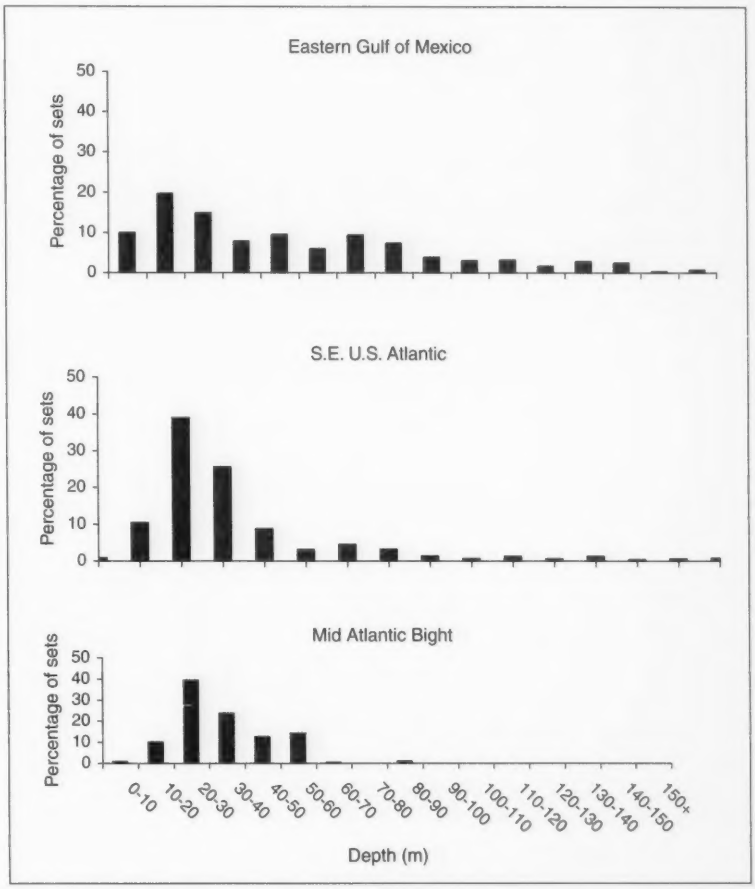

Figure 7.—Percent of all observed BLL sets by water depth and region.

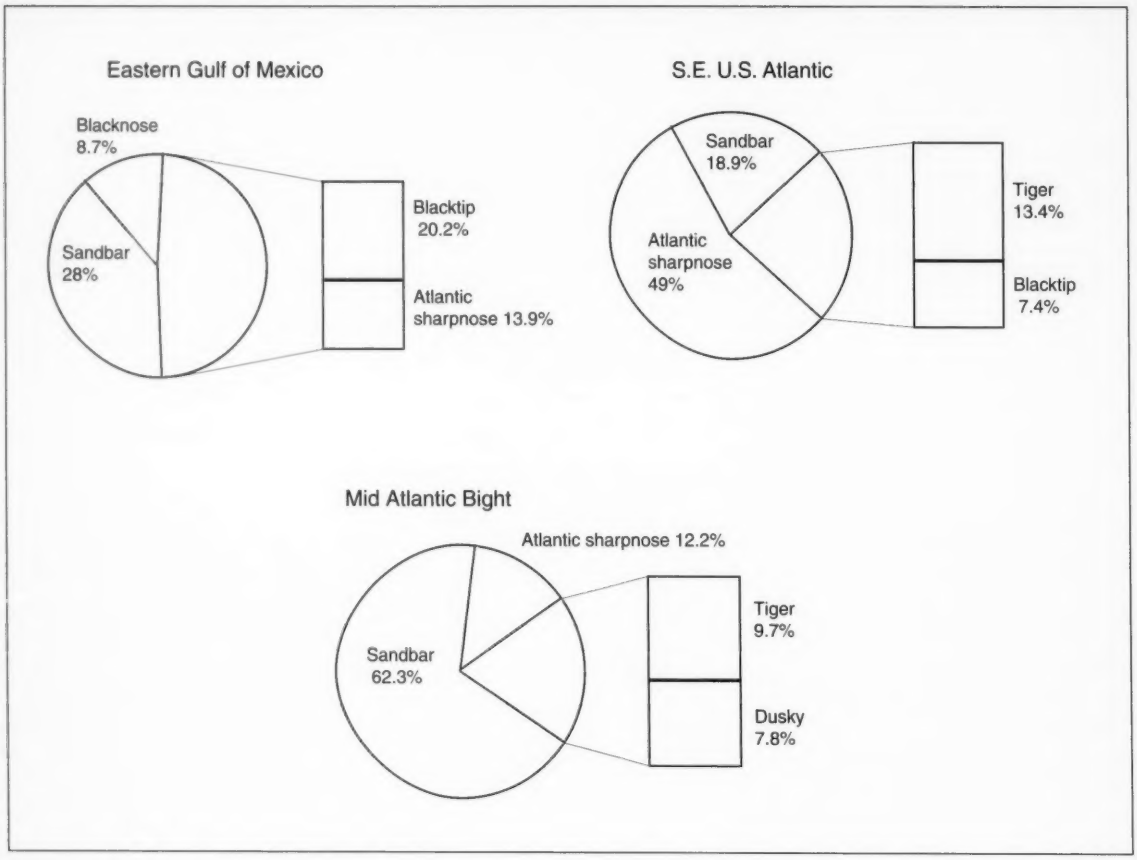

Figure 8.—Percent of individual shark species and management units represented in the total shark catch of each of the three regions.

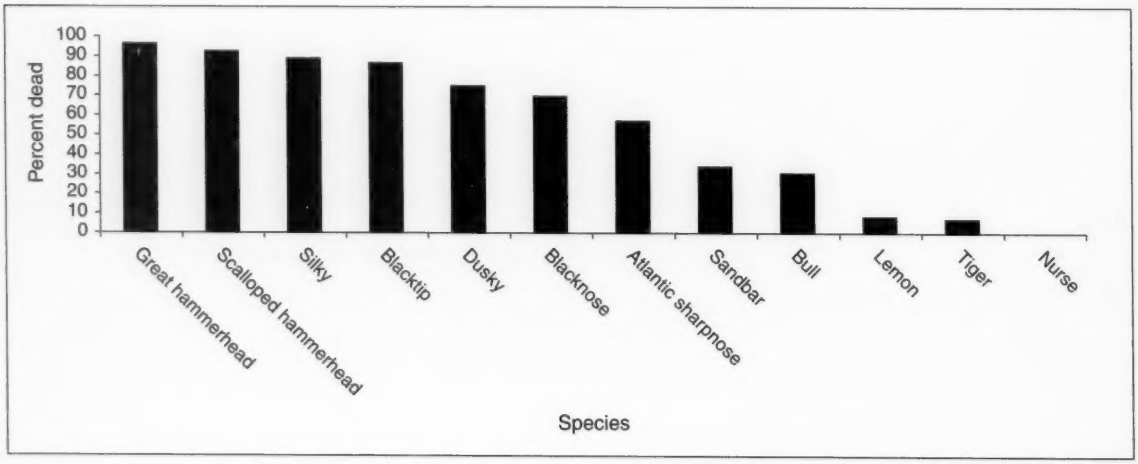

Figure 9.—Mortality rates for shark species (at the vessel) commonly observed caught in the BLL fishery.

Table 8.—Percent disposition for the dusky and Atlantic sharpnose sharks by year for all regions combined.

Species and disposition	Percent										
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total (all yrs)
Dusky											
Bait	0.0	0.0	0.5	0.7	0.0	0.0	10.0	2.5	0.0	3.7	0.5
Carcass	91.7	96.6	94.2	91.6	85.4	93.7	90.0	63.3	0.0	35.2	84.3
Discard	8.3	2.1	0.0	0.0	0.6	2.5	0.0	27.8	56.9	38.0	7.0
Display	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Escape	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Museum	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.1
Release	0.0	0.5	1.0	1.4	1.6	2.1	0.0	5.1	5.9	10.2	2.1
Tagged	0.0	0.8	3.9	6.3	12.3	1.4	0.0	0.0	37.3	13.0	5.8
Total	100.0	100.0	100.0	100.0	100.0	100.4	100.0	100.0	100.0	100.0	100.0
Alive	0.0	1.3	4.8	7.7	13.9	3.5	0.0	5.1	43.1	23.1	7.9
Dead	100.0	98.7	95.2	92.3	86.1	96.8	100.0	94.9	56.9	76.9	92.1
Atlantic sharpnose											
Bait	36.0	40.3	36.2	32.7	83.5	89.6	99.9	93.5	70.1	76.5	69.0
Carcass	15.2	58.9	59.7	58.4	8.0	9.7	0.1	0.6	15.5	0.7	23.3
Discard	47.2	0.5	1.6	8.6	3.4	0.5	0.0	5.7	13.9	19.1	6.2
Display	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Escape	0.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Museum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.1	1.5	0.0	4.8	0.0	0.0	0.0	0.3	0.0	0.8
Release	0.8	0.1	0.0	0.2	0.3	0.0	0.0	0.2	0.2	3.6	0.6
Tagged	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Alive	1.6	0.1	0.9	0.2	0.3	0.0	0.0	0.2	0.2	3.7	0.7
Dead	98.4	99.9	99.1	99.8	99.7	100.0	100.0	99.8	99.8	96.3	99.3

in at-vessel mortality when soak times exceeded 8 h. (Table 9). Mortality was <40% during sets <8 h and over 90% and 80% during sets >8 h for these species, respectively (Table 9). The blacktip, great hammerhead, and scalloped hammerhead sharks had mortality rates >67.0% during soak times longer than 4 h (Table 9).

Two species did not show increased at-vessel mortality rates with increased soak times: bull and dusky sharks. Bull shark mortality peaked at 52.3% with soak times of 16–20 h and had much lower mortality during soak times >20 h. (6.1%) (Table 9). Dusky sharks had a higher mortality rate (50.0%) during soak times <4 h compared with soak times of 4–8 h (15.4%). Overall, dusky sharks had a very high at-vessel mortality rate (Table 9). We believe that these contradictory patterns were the result of low sample sizes in certain soak time bins.

Variations appeared in the year-to-year CPUE of the major species caught in the fishery. Annual CPUE across all regions and seasons for sandbar sharks ranged from 14.3 to 41.7, but there was no significant overall CPUE change over the study period (r^2=0.04) (Fig. 10). Most of the commonly caught species showed increases in CPUE over the study period, especially the scalloped hammerhead (r^2 = 0.42), blacktip (r^2 = 0.30), and bull (r^2 = 0.28) sharks (Fig. 10). The only species with a CPUE decline was the dusky shark (r^2 = 0.07), while all other common species showed little to no change (Fig. 10).

Several species showed similar high and low point patterns in annual CPUE. Dusky, blacktip, and bull sharks all showed peaks in catch rates in 1995, followed by 2 years of declining CPUE, and then a subsequent rise to a new peak in 1999 (Fig. 10). Nurse and blacknose shark CPUE trends also followed similar patterns with a rise in catch rates during 1994–96 and 1998–99, followed by drops in 1997 and 2001, and a distinct peak in 2002 followed by a drop in 2003 (Fig. 10).

The CPUE of the LC and SC management groups also varied from year to year, ranging from 20.9 to 52.7 for LC sharks and from 2.2 to 33.1 for SC sharks between 1994 and 2001 (Fig. 11). The CPUE for SC sharks in 2000 (65.0) is inflated due to observer coverage occurring only in the SA (Fig. 11). The CPUE for both management groups showed a rising trend during the study period (r^2 = 0.51 for LC, and r^2 = 0.11 for SC) (Fig. 11).

Table 9.—At-vessel mortality rates (% dead at vessel) by soak time for nine shark species observed caught during 1994–2003.

Soak Time	Percent dead								
	Blacknose	Bull	Blacktip	Dusky	Sandbar	Tiger	Atlantic sharpnose	Scalloped hammerhead	Great hammerhead
0–4	11.3	0.0	48.6	50.0	6.5	0.0	14.3	60.0	100.0
4–8	34.8	31.3	79.6	15.4	12.7	0.0	35.3	67.9	90.9
8–12	84.9	35.1	89.4	65.8	18.9	6.4	90.9	85.0	96.6
12–16	84.4	28.3	85.4	68.1	21.8	7.1	94.1	92.6	94.9
16–20	78.3	52.3	87.4	81.8	38.5	9.6	97.1	96.1	96.8
20–24	75.0	6.1	90.0	75.0	51.3	8.6	98.6	98.0	100.0
24+	100.0	0.0	94.2	70.0	47.1	23.7	99.0	100.0	100.0

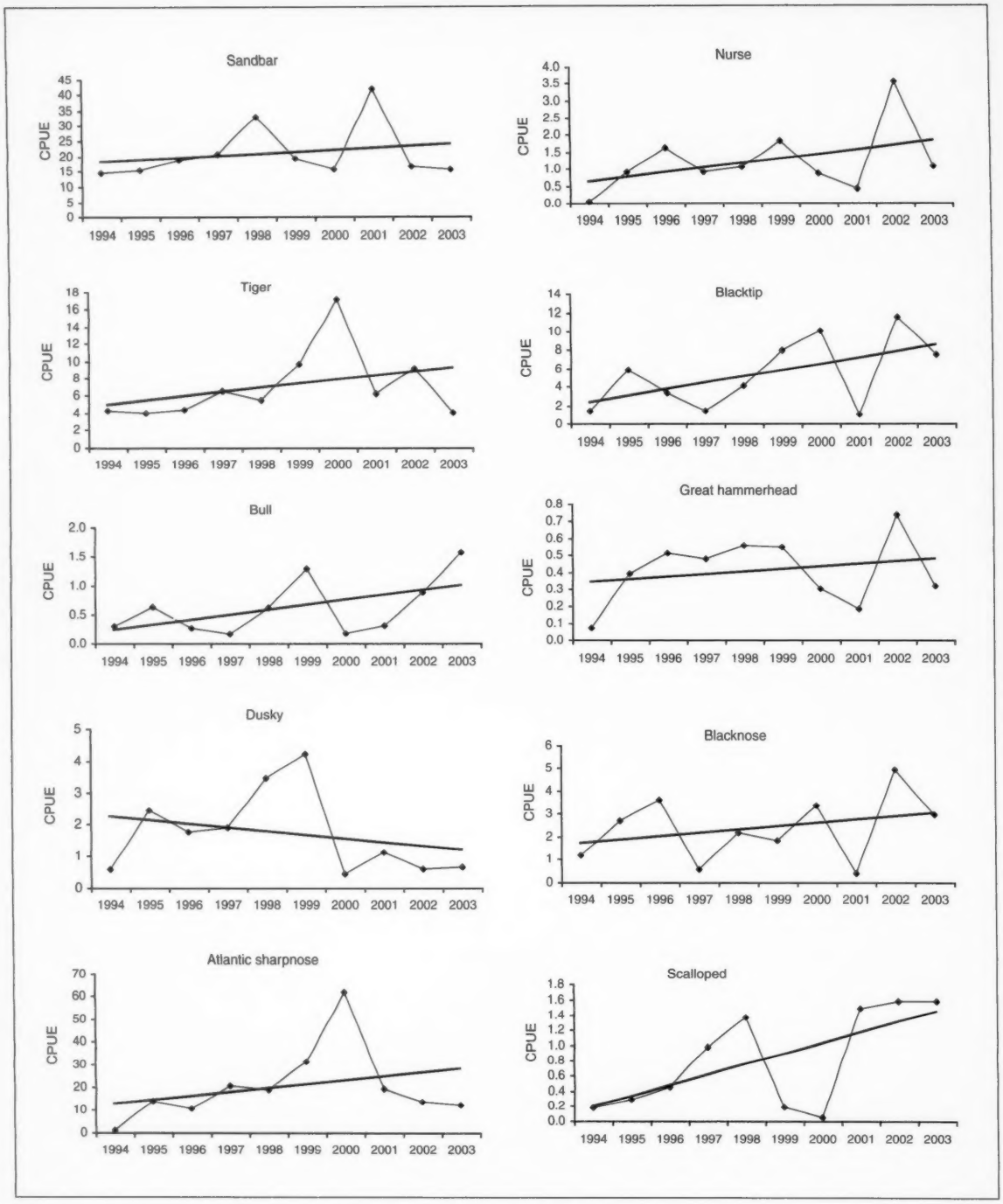

Figure 10.—Annual CPUE (sharks per 10,000 hook hours) by year for shark species commonly observed caught in the BLL fishery. The y-axis ranges are different for individual species.

Bycatch

Bycatch of non-shark species numerically represented 4.8% of the TC in the fishery, with species composition varying between the three regions. Fishermen in the EGM caught the largest percentage (62.0%) of the total bycatch, while substantially less bycatch was caught in the SE US (27.2%) and MAB (10.8%) regions.

In the EGM, bycatch represented 10.2% of the TC. This area had the fewest sharks caught (15,259) (Table 1), but had three times as much bycatch as the SE US region (3.4% TC) and over six times the bycatch of the MAB (1.6% TC). Serranid fishes represented 44% of the bycatch in the EGM. The most frequently encountered serranid was the red grouper, *Epinephelus morio,* (68.1%), followed distantly by the yellowedge grouper, *E. flavolimbatus* (7.3%); black grouper, *Mycteroperca bonaci* (6.3%); and gag grouper, *M. microlepis*, (6.1%). Anguilliformes composed another large portion of the bycatch (23.9 %), represented primarily by unidentified eels (64.6%) and king snake eel, *Ophichthus rex* (19.0%) (Fig. 12).

Several protected species were caught in the EGM, including sea turtles (Dermochelyidae, Cheloniidae), bottlenose dolphins, *Tursiops truncates,* and smalltooth sawfish, *Pristis pectinata.* One pelican, *Pelecanus sp.*, was caught (disposition not recorded), and 21 sea turtles were caught, including 15 loggerheads, *Caretta caretta* (1 discarded, 11 released alive, 3 unknown disposition); one leatherback, *Dermochelys coriacea*, of unknown disposition, and five unknown species (unknown disposition). Other protected species caught included two bottlenose dolphins (one released alive, one discarded dead), and seven smalltooth sawfish (six released alive, one unknown disposition). Unknown disposition usually meant that the gangion was cut prior to an observer being able to document whether the animal was alive or dead and whether it was released or discarded.

The SE US and MAB regions had much lower bycatch rates, which were dominated by batoids (32.9% and 59.8%, respectively). In the MAB, the butterfly ray, *Gymnura micrura* (21.4%); roughtail stingray, *Dasyatis centroura* (15.4%); and stingrays, *Dasyatis* spp. (20.3%), were commonly caught (Fig. 12), while stingrays (36.7%) dominated the batoid catch in the SE US (Fig. 12). Protected species taken in these two regions consisted of sea turtles and smalltooth sawfish. Sixteen loggerheads (nine released, four discarded, three unknown disposition), one leatherback (discarded), three unknown sea turtles (two released, one unknown disposition) and one smalltooth sawfish were caught in the SE US, and five loggerheads (one discarded, one

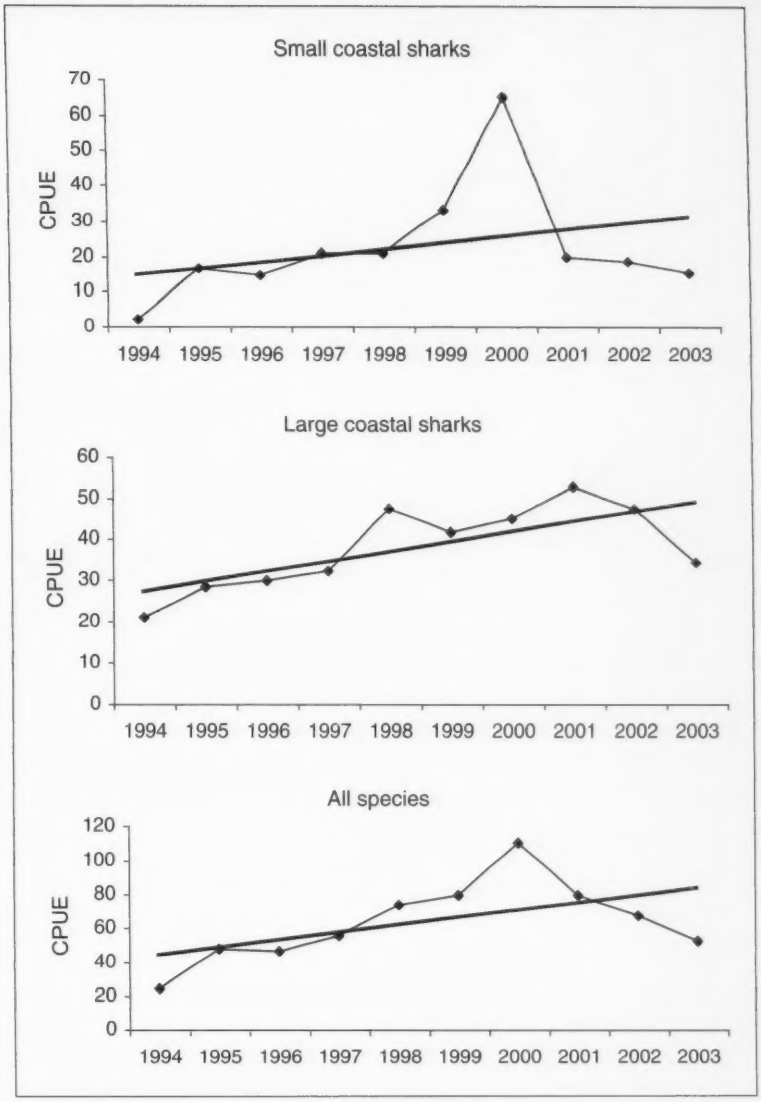

Figure 11.—Annual CPUE (sharks per 10,000 hook hours) for large coastal sharks, small coastal sharks, and all species combined.

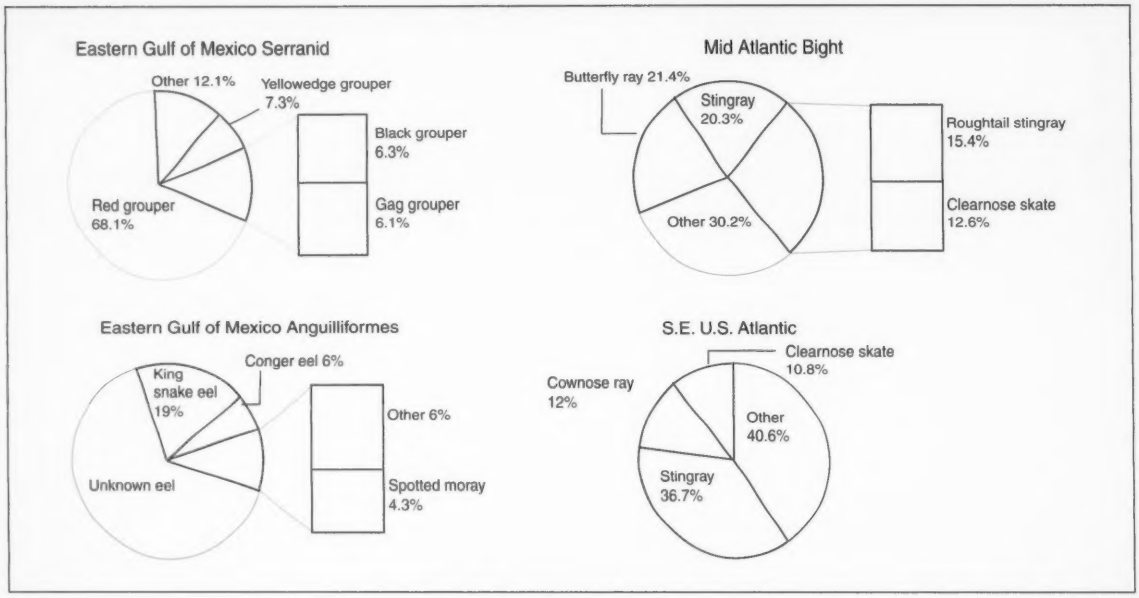

Figure 12.—Composition of bycatch by region.

released, three unknown) were caught in the MAB.

Discussion

Fishery observer programs are an important fisheries management tool, and they allow the collection of valuable high-resolution data on fishery practices, effort, catch, discards, and bycatch. These data have become increasingly important in the stock assessments used to make management decisions. As northwest Atlantic shark fisheries rapidly expanded during the 1980's and 1990's, it became clear that more information was necessary to accurately characterize the fishery and the species comprising the catch. The CSFOP was established in 1994 to help acquire this information, and it has since become one of the largest sources of data available on northwest Atlantic coastal shark resources.

The number of vessels observed during an individual season and within a year varied greatly between the voluntary and mandatory years. During voluntary years, the same vessels were generally observed during each season and over several years. This is not an ideal way to sample commercial fisheries, but was the best available option during that time period. Once the program became mandatory, the pool of vessels available for observer coverage significantly increased, although failure of some fishermen to comply with the observer program requirements (including refusing women observers, failure to notify the CSFOP prior to a BLL trip, and failure to obtain the required vessel safety inspections) kept the number of available vessels at a suboptimal level. In the future, better communication between fishermen, managers, and observer program coordinators will help to improve coverage of the fishery.

During the voluntary years, the number of sets and sea days observed depended on the observer's ability to obtain rides on BLL fishing trips. The number of sea days and sets observed varied greatly between the voluntary and mandatory years and within the two time periods. These variations could be due to factors such as weather, length of the fishing season, market price, and catch rates. Often when the market price for sharks declined, fishermen would participate in other fisheries until the price increased. In addition, a trip limit of 4,000 lb (1,814 kg) for large coastal sharks required that vessels return to port and unload once the limit is reached (NMFS[15]). Observers on vessels that caught the trip limit quickly logged fewer sea days per trip.

During the 10 years analyzed, observers recorded a wide variety of hook sizes, although only three sizes were used frequently. The different sized hooks were selected based primarily on the targeted species and also on fisherman preference. Smaller hooks were used to target smaller species (Atlantic sharpnose, blacknose), and larger hooks were used to target larger shark species (sandbar, dusky, bull). Large fluctuations in the number of hooks used per set most likely relates to vessel size, fisherman preference, and prior fishing success. Smaller vessels generally set less gear, and fishermen in areas where fishing grounds are located far from shore (i.e. North Carolina) generally set more fishing gear. Reductions in the average number of hooks used per set between 1994–97 and 1998–2003 may have been influenced by changes in regulations, such as trip

limits, which lead to a reduction in the size of vessels and therefore the amount of gear used.

Fishing gear was typically set at night and hauled back in the morning. This common fishing method was reflected in soak time and is why approximately 85% of sets had soak times less than 16 h. Sets lasting more than 16 h were typically an indirect result of the 4,000 lb trip limit implemented in 1993 (NMFS[5]). If the limit was reached before all the gear was hauled, fishermen were required to leave the remaining gear in the water while they returned to port to unload their catch. The remainder of the gear was hauled on subsequent trips. The large number of observed shallow-water sets was also a result of fishing methods, because most targeted species are located in waters <50 m deep (Compagno, 1984).

Knowledge of catch composition in multi-species fisheries is important for effective management. Observer programs help fishery managers better understand the scope of the catch composition within a fishery. While fishermen may only target one or two species, a number of species may be caught, and the mortality of each needs to be considered in the management plan. This is particularly true if species in the complex exhibit variation in their life histories and population dynamics.

Changes in catch composition can occur over time, which may indicate changes within the fishery or in the population status of particular species (Kirkwood et al., 1994; Greenstreet and Hall, 1996). The commercial BLL fishery targets LC sharks; however, a number of small coastal, dogfish, pelagic, and prohibited shark species are also caught. The fishery began by targeting sandbar and blacktip sharks for their fins and meat, but over time the Atlantic sharpnose shark also became a target for use as bait in longline sets. Regional differences in catch composition were very pronounced and were primarily due to individual species distributions, migration patterns, and fisherman preference.

Observer programs offer detailed information about the final disposition of the catch, which can be utilized to estimate total mortality in a fishery. Most catch statistics used in fisheries management are based on logbook data and landing reports, which often do not include this valuable information (Morgan and Burgess, 2005; NMFS[3]). Sharks that are caught and discarded or used for bait may never be recorded and therefore will not be counted against the quota or incorporated into fishing mortality estimates. Some species, such as dusky and white sharks, are prohibited from being landed but are often caught incidentally and discarded dead. Observer data are, therefore, the only indicator of the frequency of interactions with various protected species in this fishery.

Fishery managers must be made aware of these sources of undocumented mortalities, because they may have a major impact on the accuracy of stock assessments and the success of current and future management plans. Our results show that SC sharks have an extremely high fishing mortality rate (at-vessel mortality and disposition); however, only a small percentage of these sharks are landed for sale. This cryptic mortality illustrates the fact that a large number of sharks may not be accounted for and may never be incorporated into assessments of the fishery. The rates of mortality documented by observers can, therefore, be used by assessment scientists to extrapolate total mortality for non-landed species in the fishery.

Mortality estimates for species involved in commercial fisheries are a main component of population assessments (Simpfendorfer et al., 2005). Typically, fishing mortality is associated with those animals that are landed for sale. However, a large number of nontargeted species mortalities are not accounted for in population assessments because they are discarded at sea. As a consequence, any catch-and-release measures enacted for species with high at-vessel mortality rates will probably have little positive effect on reducing fishing mortality.

Species such as nurse, tiger, and bull sharks possibly suffer lower at-vessel mortality rates because they are not obligate ram ventilators and may not become greatly stressed when hooked (Manire and Hueter, 2001). Hammerhead species, on the other hand, are obligate ram ventilators and suffer a very high at-vessel mortality rate (Carlson et al., 2004). Fisheries observers are able to document such fishing mortality, and this provides valuable information to fisheries managers. Alternative management measures, such as reducing soak time or gear modifications, may be more helpful to species that have high at-vessel fishing mortality rates.

CPUE is a commonly used indicator of how commercial fish stock size fluctuates over time (Morgan and Burgess, 2005). It can be influenced by changes within the fishery, such as gear improvements, and changes in the targeted species and fishing areas. While CPUE is usually standardized to account for possible changes due to time constraints; this was not done for this report. Increases in CPUE for most of the targeted species in our data set maybe a result of fishermen becoming more adept at targeting and catching specific species. The results also mimic those found in the 2002 LC stock assessment (Cortes[17]), indicating an upward trend since the early 1990's.

The majority of the bycatch was represented by stingrays, groupers, and eels, which are all common inhabitants of the areas fished by the BLL fleet (McEachran and Fechhelm, 2005). There was minimal protected species bycatch compared with other fisheries (Poiner and Harris, 1996; Julian and Beeson, 1998; Witzell, 1999), most likely due to the use of BLL gear instead of PLL gear and setting fishing gear at night. While sea turtles were occasionally caught, only a few interactions with leatherback turtles were recorded, and most sea turtles were returned to sea alive. The high incidence of protected species interactions in the EGM, when

[17]Cortés, E., L. Brooks, and G. Scott. 2002. Stock assessment of large coastal sharks in the U.S. Atlantic and Gulf of Mexico. September, 2002. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Panama City Lab., Sustainable Fish. Div. Contrib. SFD-02/03-177.

compared to the SE US and MAB regions, was most likely due to heavy fishing in the Florida Key's region, where smalltooth sawfish and sea turtles more commonly occur. Overall, our data does not indicate that the shark BLL fishery is a large source of mortality for protected resources off the southeastern U.S. coast.

The CSFOP has collected a large amount of information pertaining to the shark BLL fishery over the 10 years documented in this report. Based on the observations collected during this time frame, we suggest that fishery managers consider single species monitoring and management options for this fishery. There are significant differences in the life history traits of species commonly represented in the catch, making it impossible to provide all species with the same levels of protection. The use of alternative management measures, such as limiting the soak time and/or length of gear or implementing larger time/area closures, may be beneficial to many species represented in this fishery (in particular the dusky, great hammerhead, and scalloped hammerhead sharks). The expansion of species-based monitoring efforts, both in port and at sea, in northwest Atlantic shark fisheries will help to provide much needed data for robust stock assessments. Fishery managers must continue to utilize an observer program as a tool to monitor the commercial BLL shark fishery to ensure that the resource may be sustainably managed in the future.

Acknowledgments

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Catches of Humpback Whales, *Megaptera novaeangliae*, by the Soviet Union and Other Nations in the Southern Ocean, 1947–1973

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Introduction

The great whales of the Southern Ocean were extensively exploited by modern whaling methods, with the first catches made in the Falkland Islands Dependencies region of IWC Management Area II in 1904 (Tønnesson and Johnsen, 1982; Hart, 2006). Exploitation went through several phases. Populations of humpback whales, *Megaptera novaeangliae*, and blue whales, *Balaenoptera musculus*, around South Georgia crashed around the time of World War I, and further exploitation occurred in other regions into the 1930's. There was a hiatus in whaling during World War II, but large-scale catches resumed in Antarctic waters after 1945.

As is now well known, between 1947 and 1973 the Soviet Union conducted large-scale illegal whaling throughout much of the North Pacific, Indian, South Atlantic, and Southern Oceans (Yablokov, 1994, 1995; Yablokov et al., 1998; Ivashchenko et al., 2007; Berzin, 2008; Clapham and Ivashchenko, 2009). This campaign involved the killing of animals of all ages and species, irrespective of quotas, regulations, and protected status established at the time by the International Whaling Commission (IWC). Much of the true catch data have now been made available through the efforts of former Soviet biologists working aboard the various factory ships involved; these data involve the number of animals taken, and sometimes additional details such as location of catch and biological characteristics of the whales.

In the Southern Hemisphere alone, almost 100,000 whales were secretly killed by the U.S.S.R. and not reported to the IWC (Yablokov et al., 1998; Clapham and Baker, 2002). Of this total, some 46,000 were humpback whales. Although the locations (general or specific) of many of these catches are known, the numbers of animals taken are not. Here we present the best available data on Soviet catches of humpback whales in the Southern Ocean.

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ABSTRACT—From 1947 to 1973, the U.S.S.R. conducted a huge campaign of illegal whaling worldwide. We review Soviet catches of humpback whales, Megaptera novaeangliae, *in the Southern Ocean during this period, with an emphasis on the International Whaling Commission's Antarctic Management Areas IV, V, and VI (the principal regions of illegal Soviet whaling on this species, south of Australia and western Oceania). Where possible, we summarize legal and illegal Soviet catches by year, Management Area, and factory fleet, and also include information on takes by other nations. Soviet humpback catches between 1947 and 1973 totaled 48,702 and break down as follows: 649 (Area I), 1,412 (Area II), 921 (Area III), 8,779 (Area IV), 22,569 (Area V), and 7,195 (Area VI), with 7,177 catches not currently assignable to area.*

In all, at least 72,542 humpback whales were killed by all operations (Soviet plus other nations) after World War II in Areas IV (27,201), V (38,146), and VI (7,195). More than one-third of these (25,474 whales, of which 25,192 came from Areas V and VI) were taken in just two seasons, 1959–60 and 1960–61. The impact of these takes, and of those from Area IV in the late 1950's, is evident in the sometimes dramatic declines in catches at shore stations in Australia, New Zealand, and at Norfolk Island.

When compared to recent estimates of abundance and initial population size, the large removals from Areas IV and V indicate that the populations in these regions remain well below pre-exploitation levels despite reported strong growth rates off eastern and western Australia. Populations in many areas of Oceania continue to be small, indicating that the catches from Area VI and eastern Area V had long-term impacts on recovery.

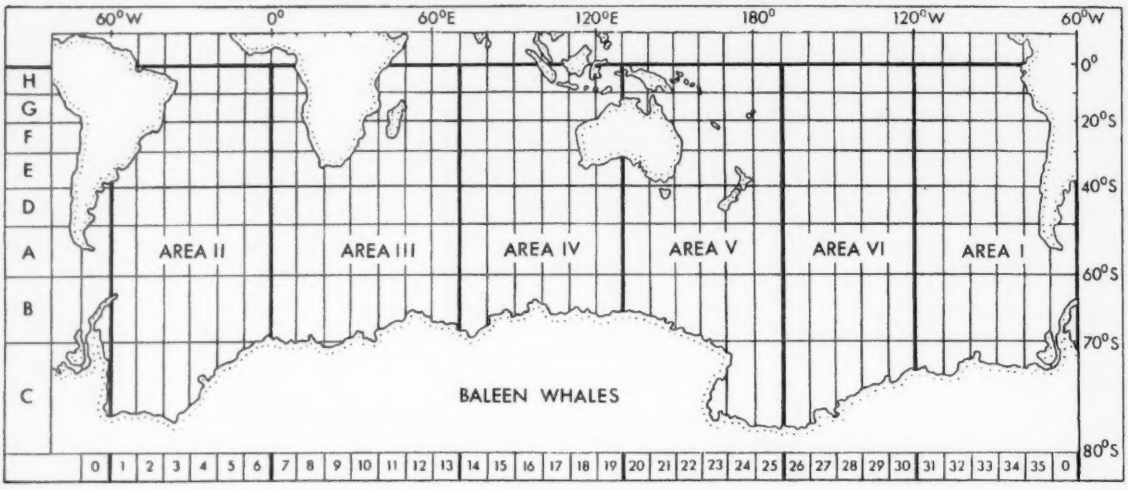

Figure 1.— Southern Hemisphere baleen whale management areas. Source: IWC, 1980: p. 582.

cific) of most of these catches have been revealed, many discrepancies and gaps have remained which have complicated efforts to determine the potential impact of these takes on the stocks concerned. Here, we detail illegal Soviet catches of humpback whales in the Antarctic region during 1947–73, and we attempt to assign these catches to each of the six management areas (termed Areas I–VI) defined by the IWC (IWC, 1980 and Fig. 1). We also provide data on humpback whale catches by factory fleet, as well as total catches (by the U.S.S.R. and other nations) for Areas IV, V, and VI.

Data Sources

From 1947 to 1973, Soviet catches of humpback whales were made by four floating factory fleets, which operated at various times during the period: *Slava* (1946–66), *Sovetskaya Ukraina* (1959–73), *Yuri Dolgorukiy* (1960–1973), and *Sovetskaya Rossiya* (1961–73). The total catch during the entire period was 48,702 humpbacks; only 2,710 of these catches were reported to the IWC.

Here and previously, the first source for these catch records was *Soviet Antarctic Whaling Data (1947–1972)* (Yablokov, 1995, commonly referred to by the color of its cover as "the green volume"). This provides details of reported vs. true catch data for each of the four floating factory fleets; in many but not all cases these catches are broken down by Area. However, there are two inconsistencies in this record:

1) If Area totals for each whaling season and factory ship are summed from the individual tables, they sometimes do not agree with the summary totals given for each factory ship for the entire period of operation. Sometimes this is because catches which were not assigned to Area are omitted from the summary table's totals; sometimes it appears to be a simple mathematical error.
2) Some data shown in catch summaries provided by Zemsky et al. (1995, 1996) are not included in the green volume, and (less often) the other way around.

The tables presented in this paper make the assumption that the data given in Zemsky et al. (1995, 1996) are more complete than those in the green volume, and therefore they represent a more accurate record; the only exceptions are a few places where Zemsky et al. (1995, 1996) have gaps that the green volume fills (e.g. the 1967–68 season for *S. Ukraina*). Thus, the tables represent a combination of information derived from both sources.

The data derived from the green volume for the *Slava* and *Yuri Dolgorukiy* needed no correction (i.e. the numbers were consistent between the Zemsky papers and the green volume). The *S. Ukraina* green volume data required some minor adjustments. The *S. Rossiya* data in the green volume were the most problematic. Data for non Soviet whaling operations were taken from summaries in various published sources, primarily Chittleborough (1965).

The 1959–60 and 1960–61 Antarctic Seasons

Of the 48,702 humpback whales caught by the U.S.S.R., more than half were killed in two Antarctic whaling seasons: 1959–60 and 1960–61. The Area breakdowns for *Slava* and *S. Ukraina* in 1959–60 were based upon original catch records and knowledge of where the fleets were operating (reported in less detail by Mikhalev, 2000). Operations in that season occurred between December and March in Area V, with an incursion into Area VI in the second half of March; because the exact number of whales taken in Area VI is

not known, March catch totals for both fleets have been divided evenly between V and VI.

The Area breakdowns for *Slava* and *S. Ukraina* for 1960–61 were taken from Mikhalev (2004) and Zemsky et al. (1996), which together provide information on where the two fleets (notably the latter) were operating each month, together with catch totals for each month. In general terms, the fleets were in Area IV in November, Area V in December–January, and Area VI in February–March; but because there were a few days that did not quite fit this pattern, some catches (though not a lot) may have been assigned by us to the wrong Area.

Catch Summary

True Soviet whaling catches are reported by factory ship, year, and Area in a series of tables below, as follows: *Slava* (Table 1), *Sovetskaya Ukraina* (Table 2), *Yuri Dolgorukiy* (Table 3), *Sovetskaya Rossiya* (Table 4), all fleets combined, by Area (Table 5), by season and factory fleet (Table 6). Non Soviet catches of humpback whales in the same period came primarily from Areas IV and V; these are summarized in Tables 7 and 8, respectively.

Table 9 gives total catches for the entire period: 27,201 (Area IV), 38,146 (Area V), and 7,195 (Area VI), with 7,177 catches not assignable to an area. Including both Soviet and non Soviet catches, at least 72,542 humpback whales were killed in Areas IV, V, and VI during the post-war period.

Discussion

Following World War II, almost half the total of illegal whaling in the Southern Hemisphere by the U.S.S.R. were of humpback whales, which was probably the most abundant species in the areas in which the Soviet fleets were working, and thus provided the fastest way to meet the production targets in the industrial plan that governed everything. However, blue whales, sperm whales, sei whales, Bryde's whales, minke whales, and right whales were also killed in large numbers

Table 1.—Number of humpback whales killed by the *Slava*, by area and season, from 1946–47 to 1965–66. All catches from 1957–58 and 1958–59 have been assigned to Area IV, although it is likely that up to about 300 of these animals were taken in locations to the west of this region while in transit (Mikhalev, personal recollection). The 1959–60 catches are known to have come largely from Area V, with some others from western Area VI (Mikhalev, 2000); therefore, while the exact numbers per Area are not known, the total has been apportioned on this basis. The Area totals for 1960–61 (when *Slava* and *Sovetskaya Ukraina* were operating generally together) are estimated from information about fleet movements given in Mikhalev (2004); while those figures are not entirely accurate because of the grouping of some catches across the boundary of Areas V and VI, they are unlikely to be significantly in error.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Unknown	Total
1946–47 to 1956–57							3,564	3,564
1957–58				2,235				2,235
1958–59				4,039				4,039
1959–60					4,930	495		5,425
1960–61				19	2,415	1,612		4,046
1961–62	6		9	259	216	1,156		1,646
1962–63	6		16	453	168	103		746
1963–64							97	97
1964–65								0
1965–66			13	61	7			81
Total	12	0	38	7,066	7,736	3,366	3,661	21,879

Table 2.—Number of humpback whales killed by the *Sovetskaya Ukraina*, by area and season, 1959–60 to 1967–68.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Unknown	Total
1959–60					6,848	672		7,520
1960–61				42	3,941	1,590		5,573
1961–62							1,078	1,078
1962–63							667	667
1963–64		4	11	24	260			299
1964–65							3	3
1965–66							710	710
1966–67	238			51	18	180		487
1967–68							181	181
1968–69								0
1969–70								0
1970–71								0
1971–72								0
1972–73							1	1
Total	238	4	11	117	11,067	2,442	2,640	16,519

Table 3.—Number of humpback whales killed by the *Yuri Dolgorukiy*, by area and season, from 1960–61 to 1972–73.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Unknown	Total
1960–61	2	5	33	181	2,274	415		2,910
1961–62	191		17	108	267	512		1,095
1962–63		2	75	868				945
1963–64			27	118				145
1964–65			67	18				85
1965–66		774	265					1,039
1966–67		90	266	4				360
1967–68		535	84	4				623
1968–69								0
1969–70								0
1970–71								0
1971–72	3							3
1972–73		2						2
Total	196	1,408	834	1,301	2,541	927	0	7,207

Although the true catch figures have been known for some time, assigning these catches to Management Area has in many cases proved difficult. Contradictions in published information and lack of availability of detailed catch positions has introduced uncertainty into efforts to assess the impact of these catches on the various stocks concerned. Although more detailed information may become available from previously unsearched archives in the former Soviet Union, the summaries given here are the most accurate

Table 4.—Number of humpback whales killed by the *Sovetskaya Rossiya*, by area and season, from 1961–62 to 1972–73. The difference between the data given in the green volume and the total number reported by Zemsky et al. (1996) are assigned to unknown area. The overall total of 3,097 agrees with that in Zemsky et al. (1996).

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Unknown	Total
1961–62	203		3	9	1,069	404		1,688
1962–63							573	573
1963–64			34	85	4		27	150
1964–65				56	61		29	146
1965–66							223	223
1966–67				103	85			188
1967–68			1	42	6	56	20	125
1968–69							2	2
1969–70								0
1970–71								0
1971–72								0
1972–73							2	2
Total	203	0	38	295	1,225	460	876	3,097

Table 5.—Combined humpback whale catch totals by area and year for all four Soviet factory fleets, 1946–73. The 3,564 unassigned catches from 1946–47 to 1956–57 seasons were all taken by the *Slava*.

Year	Area I	Area II	Area III	Area IV	Area V	Area VI	Unknown	Total
1946–47 to 1956–57							3,564	3,564
1957–58				2,235				2,235
1958–59				4,039				4,039
1959–60					11,778	1,167		12,945
1960–61	2	5	33	242	8,630	3,617		12,529
1961–62	400		29	376	1,552	2,072	1,078	5,507
1962–63	6	2	91	1,321	168	103	1,240	2,931
1963–64		4	72	227	264		124	691
1964–65			67	74	61		32	234
1965–66		774	278	61	7		933	2,053
1966–67	238	90	266	158	103	180		1,035
1967–68		535	85	46	6	56	201	929
1968–69							2	2
1969–70								0
1970–71								0
1971–72	3							3
1972–73		2					3	5
Total	649	1,412	921	8,779	22,569	7,195	7,177	48,702

Table 6.—Southern Hemisphere humpback whale catches for all four Soviet floating factories, 1946–73. Source: Zemsky et al. (1995, 1996), except for 1967–68 *S. Ukraina* data, which come from the green volume.

Season	*Slava*	*S. Ukraina*	*Yuri D.*	*S. Rossiya*	Total
46–47	1				1
47–48					0
48–49	112				112
49–50	511				511
50–51	945				945
51–52	599				599
52–53	311				311
53–54	213				213
54–55	361				361
55–56	236				236
56–57	275				275
57–58	2,235				2,235
58–59	4,039				4,039
59–60	5,425	7,520			12,945
60–61	4,046	5,573	2,910		12,529
61–62	1,646	1,078	1,095	1,688	5,507
62–63	746	667	945	573	2,931
63–64	97	299	145	150	691
64–65		3	85	146	234
65–66	81	710	1,039	223	2,053
66–67		487	360	188	1,035
67–68		181	623	125	929
68–69				2	2
69–70					0
70–71					0
71–72			3		3
72–73		1	2	2	5
Total	21,879	16,519	7,207	3,097	48,702

accounting available to date, and the reported totals are unlikely to be significantly in error.

The large number of humpbacks killed by the U.S.S.R. in Areas IV and V from about 1957 to 1961 precipitated major declines in catches at shore stations in Australia and New Zealand, notably those reliant on whales from Area V. More than 6,000 whales were removed from Area IV in 1957–58 and 1958–59 by the *Slava* fleet, and this was followed by a notable decline in catches at the two western Australian stations of Carnarvon and Albany, which in 1959 took only 700 humpbacks from an assigned quota of 1,175 (Table 7).

More dramatic was the situation in Area V following the huge Soviet catches in 1959–60 and 1960–61 (a total of 25,474 whales, of which about 20,630 came from Area V). In 1961, the eastern Australian stations of Tangalooma and Byron Bay failed for the first time to reach their catch quota, and the fishery collapsed the following year (Table 8). The decline was even more apparent to the east at the stations in New Zealand, where the catch dropped from 361 whales in 1960 to 80 (1961) and then 32 (1962). Similarly, in 1962 the station at Norfolk Island caught only 4 whales from a quota of 170.

The total post-war catches by all nations from Areas IV and V (27,201 and 38,146 humpbacks, respectively) were very large. If one compares these figures to current estimates of abundance and initial population size (IWC, 2006), it is apparent that the current sizes of these populations remain well below their pre-exploitation levels despite reported strong growth rates in some areas. Jackson et al. (2008) explored this issue using a two-stock Bayesian density-dependent logistic population model. Their median posterior estimate of carrying capacity for eastern Australia (broadly equivalent to Area V) was 26,383–31,400, with a median recovery estimate in 2008 of 27–31% of initial population size.

The situation with Area VI (total known catch 7,195 whales) is less clear than for Areas IV and V. Median posterior estimate of carrying capacity for Oceania of Jackson et al. (2008) was 16,022–22,957, with a median recovery estimate of 20–25% of initial population size. This estimate, together with the relatively low abundance of humpback whales observed in many parts of this region today (New Zealand, New Caledonia, the Cook Islands, Fiji, Tonga, American Samoa, and French Polynesia) suggests a slow recovery from the large-scale overexploitation perpetrated by the U.S.S.R. This situation has prompted recent concern over the status of humpback whales in Oceania, and has led to that sub-population being categorized as "endangered" by the IUCN (Childerhouse et al., 2008).

Acknowledgments

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Table 7.—Other (non Soviet) catches of humpback whales from Area IV, 1949–62. Point Cloates, Carnarvon, and Albany are all on the west coast of Australia. Source: Chittleborough (1965: Table 1).

	Point Cloates		Carnarvon		Albany			
Year	Quota	Catch	Quota	Catch	Quota	Catch	Antarctic (pelagic)	Total
1949	600	190					0	190
1950	600	348	600	40			779	1,167
1951	600	574	650	650			1,112	2,336
1952	600	536	600	600	50	51	1,127	2,314
1953	603	603	600	600	100	100	193	1,496
1954	600	600	600	600	120	120	258	1,578
1955	500	500	500	500	126	126	28	1,154
1956	Transferred[1]		1,000	1,000	120	119	832	1,951
1957			1,000	1,018	120	102	0	1,120
1958			1,000	885	120	82	0	967
1959			1,000	541	175	159	1,413	2,113
1960			750	440	120	105	66	611
1961			475	475	105	105	4	584
1962			540	503	100	40	56	599
Total	West coast of Australia: 12,312						5,868	18,180

[1]Quotas and catches transferred to Carnarvon.

Table 8.—Other (non Soviet) catches of humpback whales from Area V, 1949–62. Tangalooma (Queensland), and Byron Bay (New South Wales) are both in eastern Australia. Source: Chittleborough (1965: Table 2).

	Tangalooma		Byron Bay		Norfolk Island				
Year	Quota	Catch	Quota	Catch	Quota	Catch	New Zealand	Antarctic (pelagic)	Total
1949							141	0	141
1950							79	903	982
1951							111	162	273
1952	600	600					122	146	868
1953	700	700					109	504	1,313
1954	600	598	120	120			180	0	898
1955	600	600	120	120			112	1,097	1,929
1956	600	600	120	120	150	150	143	194	1,207
1957	600	600	121	121	120	120	184	0	1,025
1958	600	600	120	120	120	120	183	0	1,023
1959	660	660	150	150	150	150	318	885	2,163
1960	660	660	150	150	170	170	361	931	2,272
1961	660	591	150	140	170	170	80	293	1,274
1962	600	68	150	105	170	4	32	0	209
Total	Eastern Australia: 8,307						2,155	5,115	15,577

Table 9.—Known total post-war catches (U.S.S.R. and other nations) of humpback whales from Areas IV, V, and VI, and migratory corridors directly north of these areas (e.g. Australia and New Zealand). There were an additional 7,177 Soviet catches that were not assignable to an Area.

Year/Source	Area IV	Area V	Area VI	Total
U.S.S.R., 1959–60		11,778	1,167	12,945
U.S.S.R., 1960–61	242	8,630	3,617	12,489
Other U.S.S.R., 1949–73	8,779	2,161	2,411	13,351
Australia–NZ, 1949–62	18,180	15,577		33,757
Total	27,201	38,146	7,195	72,542

A Whale of a Deception

PHIL CLAPHAM and YULIA IVASHCHENKO

In late October of 1966, an imposing ship steamed quietly through the placid waters of the Suez Canal. Clad in drab industrial gray, and flying a Soviet hammer and sickle flag at her masthead, the vessel was accompanied by a large fleet of smaller craft. Any observer able to decipher Cyrillic script could have read, in rusting metallic letters on her bow, the name *Sovetskaya Ukraina*. The more experienced would perhaps have identified her as a whaling factory ship, traveling with her attendant fleet of catcher boats and scouting vessels on a transit that would take them south into the Red Sea and beyond.

Although the whaling fleet may have presented a noteworthy sight, *Sovetskaya Ukraina*'s passage through the Canal was nothing unusual. As far as anyone knew, she was bound once more for the great whaling grounds of the Antarctic, and was simply taking the shortest route there from her home port of Odessa on the Black Sea.

A few days later, however, as the fleet entered the Gulf of Aden, it abruptly broke its southbound track. Unmarked by anyone except some local fishermen, *Sovetskaya Ukraina* and her catchers turned to the northeast. As they cruised within sight of the desert coastline of Oman, the fleet fanned out. On November 4th, they began to kill whales.

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A whaling fleet engaged in the practice of whaling is hardly cause for comment. What made these catches unusual, however, was that almost all of them were illegal.

Over the next two weeks, the vessels of the Soviet fleet swept the northwestern Indian Ocean. Their search for whales took them from Oman to the Gulf of Kutch off Pakistan, through offshore waters west of the Indian city of Bombay, and south to the Maldive Islands. By the time *Sovetskaya Ukraina* finally resumed her course for the Antarctic on November 21st, her catcher boats had delivered more than three hundred whales to the huge floating factory for processing. Most of the animals had been either humpbacks, *Megaptera novaeangliae*, or blue whales, *Balaenoptera musculus*, two species that were officially considered "protected" under the international regulations that governed commercial whaling.

When the Soviet fleet reached the Antarctic, the pattern was repeated. Already-depleted and supposedly protected stocks of whales were plundered for several months until the onset of the austral winter. Finally, as the weather turned increasingly foul, the factory ship and her catchers began the long journey home.

In keeping with its obligations as a signatory to international whaling agreements, the Soviet government dutifully reported that the *Sovetskaya Ukraina* fleet had taken a total of 2,727 whales during the 1966–67 season, all of them "legal" species such as sperm, *Physeter macrocephalus*; fin, *Balaenoptera physalus*; and sei, *Balaenoptera borealis*; whales. The actual catch was 5,127—a difference of 2,400 whales. Nor was *Sovetskaya Ukraina* operating alone. Elsewhere, two other Soviet factory fleets had taken a further 5,323 animals that went unreported. In a single season, 7,723 whales had literally disappeared without a trace.

This was neither the first nor the most productive year for illegal whaling. In just two Antarctic seasons (1959–60 and 1960–61), *Sovetskaya Ukraina* (Fig. 1) and another floating factory, *Slava* (Fig. 2), killed a staggering 25,000 humpback whales in the waters south of Australia and New Zealand.

This flagrant disregard for international agreement, and for the declining status of Antarctic whale stocks, was no renegade act of piracy by the commanders of the fleets concerned. The illegal catches of that whaling season were simply the latest in a carefully planned official strategy that had been implemented almost 20 years before. Few people suspected it, but the Soviet Union had been plundering the world's whale populations with abandon since 1947. By the time that the illegal catches finally ended in 1973, the Soviets had killed probably over 200,000 more whales than they had officially reported. And in the process, they had quite possibly succeeded in dooming at least one population of whales—that of the right whale in the eastern North Pacific—to extinction.

The story of whaling in the twentieth century is largely one of excess. It is also a story of technology finally catching up with greed.

In Herman Melville's day, whales were caught using methods that had changed little in centuries. Men set out in small boats and had to approach dangerously close to a whale before hurling

a hand-held harpoon at the animal's huge body. It was a risky business, and not very efficient. Whales could escape. Boats could be overturned. And some species were simply too fast to be caught.

By the turn of the 20th century, two inventions had changed all this. Introduction of the steam engine allowed men to hunt even the fastest whales. Species which had been out of reach of vessels powered solely by wind in a sail, or human strength applied to oars, were suddenly fair game. In particular, whalers could now easily catch the greatest prizes of all, the huge blue and fin whales. At the same time, the invention of the explosive harpoon provided whalers with a means to kill whales more quickly and efficiently, and from a distance.

This revolution in whaling was completed with two more innovations. The compressor solved the long-standing problem of how to prevent whale carcasses from sinking: now, whalers could pump compressed air into a dead whale's body to keep it afloat. Finally, in the 1920's, the factory ship was introduced, freeing whalers from their ties to land. Factory fleets could remain at sea for months, killing and processing large numbers of whales with grim efficiency. Whaling had finally come into the industrial age.

With timing that was ironically coincidental, the beginning of the 20th century also brought the discovery of the richest whaling grounds in the world. In 1904, whaling vessel captained by the Norwegian C. F. Larsen ventured into the largely unexplored waters of the Southern Ocean, and there the crew found whales beyond their wildest dreams. Feeding in the highly productive polar waters were huge populations of almost every commercially valuable species. Blue whales; fin whales; humpbacks; southern right whales, *Eubalaena australis*; sperm whales; and others abounded. Some of the blue whales exceeded 100 feet in length. For a while, it seemed as though this great bounty would have no end, and vessels flocked to the bottom of the world to claim their share. Modern whaling had found its great playground, and a slaughter almost unparalleled in the history of wildlife exploitation was about to begin.

Figure 1.—Soviet whaling factory ship *Sovetskaya Ukraina* (right) moored with her sister ship *Sovetskaya Rossiya.* They were the two largest whaling factory ships ever built. Year and photographer unknown.

In the Southern Hemisphere alone, the whaling industry would kill almost 900,000 whales over the next four decades. By the end of World War II, it had become clear to even the most reluctant whalers that some sort of quota system was needed to prevent the commercial extinction of the world's whale stocks. In 1946, the whaling nations—including the Soviet Union—signed the International Convention for the Regulation of Whaling. The Convention created the International Whaling Commission, a body which met annually to oversee research on whale populations and to set scientifically based quotas that would theoretically balance the industry's revenues with the need for long-term conservation of populations.

Not unpredictably, a process that was conceived as a necessarily good idea quickly fell victim to the desire for profit. Since whales are difficult to study, it was virtually impossible to obtain indisputable proof to support predictions of population crashes. There was frequently doubt, and its benefit was

Figure 2.—Soviet factory ship *Slava*. Year and photographer unknown.

Figure 3.—Yuri Mikhalev, Odessa 2008. Photo by Phil Clapham.

never awarded to the whales. During the 1950's, the whalers continued to slaughter their quarry in record numbers. In just 10 years, more than a quarter million fin whales were killed in the Southern Ocean, together with tens of thousands of other whales.

By the end of the decade, virtually all objective scientists recognized that many whale populations were being exploited well beyond the limits of reason. Over the next few years, as catches declined and some populations received complete protection from hunting, it became clear that the International Whaling Commission's intention to oversee management based upon sustainable exploitation had fallen short of reality. As it turned out, the Soviets were secretly ensuring that this shortfall was considerably greater than anyone could have imagined.

Yuri Alexeich Mikhalev (Fig. 3) knows the truth about Soviet whaling better than most. In 1964, Mikhalev left Odessa on board *Sovetskaya Ukraina*, bound for the Southern Ocean. He was 26. As a young biologist with a keen interest in marine mammals, Mikhalev viewed his employment as a valuable opportunity to conduct research using the many carcasses supplied by the whaling fleet.

Mikhalev's reality check began with his very first whale. Some time after the fleet had transited Suez, one of the catchers killed a Bryde's whale, *Balaenoptera edeni*, in the Gulf of Aden. Bryde's whales are fast, sleek animals that live their lives (unlike other baleen whales) entirely in warm waters. They are so similar to another species, the sei whale, that distinguishing the two at sea is notoriously difficult. Not so on the deck of a factory ship, where one has the leisure to examine an animal closely. The head of a Bryde's whale is marked by three prominent ridges running lengthways down the top, a feature absent in any other species. Although Mikhalev had never seen a whale before, he had studied well and knew what the animal lying before him was.

To his surprise, the senior biologist on board recorded the catch in the official log as a sei whale. Mikhalev shyly drew the biologist's attention to the head ridges and pointed to the description of Bryde's whale in a book written by Avenir Tomilin, the most eminent of Russian whale biologists (Tomilin, 1957). "Yes," said the biologist, "but the KGB Commissar on board tells me I am to record it as a sei whale, so that's what it's going to be." Only later did Mikhalev understand the problem with the Gulf of Aden catch. Since Bryde's whales are not found in Antarctic waters, and since the fleet was not supposed to be whaling anywhere else, reporting a catch of this species would raise suspicions.

The weeks that followed brought many more illegal catches, and Mikhalev gradually came to the realization that his country was engaged in a large-scale violation of whaling regulations. One day, he hesitantly broached the topic with the Commissar. "He told me that

everyone was doing it," says Mikhalev. "The Japanese, the Norwegians—everyone. They were all breaking the rules. It was only much later that I found out this wasn't true."[1]

Mikhalev also discovered that, in addition to the "official" record of catches that was submitted to the International Whaling Commission, a second log was maintained as well. These secret logs gave the true catch data for each expedition, and many years later they were to prove instrumental in setting the record straight.

Because of the extent of the deception, security on board whaling vessels was tight even by Soviet standards. They rarely visited foreign ports, and when they did the crew was either confined on board or sent ashore in groups of two or three, and always escorted. Mikhalev also recalls preparation for more extreme measures. One day he was standing on the bridge of *Sovetskaya Ukraina* as she sailed through the narrow straits of the Dardanelles off the Turkish coast. He remarked to the captain how close to shore they were and how tempting it might prove for someone to jump overboard and swim to land. "In that case," replied the captain, " I have orders to place the ship between the man and the beach so that he can be retrieved. And if that fails, I'm supposed to run him over."

Mikhalev was on board *Sovetskaya Ukraina* during her 1966–67 season, and has unpleasant memories of the time spent in the northern Indian Ocean. "Conditions on board were terrible. It was incredibly hot, and the vessels had no good ventilation—they were built for the Antarctic, not the tropics. Everything smelled of diesel fuel and butchered whales." Several men died as a result of the conditions, and another took his own life.

During that trip, the fleet killed 238 humpback whales in just ten days in the Arabian Sea. Mikhalev describes the merciless efficiency with which the animals were hunted down. "*Sovetskaya Ukraina* had more catchers than any other factory ship—twenty-five. All the catchers would fan out into a long line, so that each boat was just within sight of the one on either side of it. When you saw the catcher next to you stopped, you knew that they had found whales. When that happened, everyone would converge on the spot, kill every animal in the area, then move on."

Disturbed by this reckless pillaging of a resource, Mikhalev and some other biologists took the courageous step of complaining to the authorities. Their response was to stop Mikhalev's pay for 8 months. Nonetheless, he persisted, writing letters to the Ministry of Fisheries. After several such letters with no response, he and his dissenting colleagues were one day summoned to Moscow and called before the minister himself, a man named Ishkov who was so influential that he was jokingly referred to as the "eternal" minister of Soviet fisheries.

Mikhalev recalls Ishkov's response to their concerns. "He said to us, 'OK, I will stop this whaling tomorrow if you tell me what you will replace it with in the Five-Year Plan—how you will replace all the things we get from the whales now.' Of course we couldn't do that." When Mikhalev suggested that the whaling would leave no whales for their grandchildren, the minister laughed grimly. "He said, 'Your grandchildren? You talk to me about your grandchildren? Your grandchildren aren't the ones who can remove me from my job!'"

A similar confrontation occurred some years later with the Vice-Minister for Fisheries, a man named Ritov. Ritov promised to set up a commission to investigate, but despite Mikhalev's cooperation in providing incontrovertible evidence of the falsification of data, the commission turned in a watered-down report that implicated no one. And Mikhalev's career was essentially ruined.

As fruitless as these meetings were, they served to provide confirmation of something they had all suspected: that the illegal catches represented official policy. Ironically, Vice-Minister Ritov would have bigger problems to worry about than Mikhalev's grandchildren. Some years later, he was executed for corruption.

Figure 4.—Alexei Solyanik. Photo by Yuri Mikhalev.

No one is more emblematic of the story of Soviet whaling, and no one more notorious, than Alexei Nikolaievich Solyanik (Berzin, 2008).[2] Solyanik (Fig. 4) was by all accounts a ruthless man who rose quickly to prominence in the Soviet whaling industry, and his success at sea was such that he received numerous awards from the state, including the much-coveted "Hero of Socialist Labor." Solyanik was appointed the "General Captain-Director" of not one whaling fleet, but two: *Slava* and *Sovetskaya Ukraina*, and with these huge floating factories he roamed the

[1]Actually, this is not strictly correct. Japan is now known to have falsified catch data on sperm and Bryde's whales in their coastal fishery, up to at least 1987 (Kondo and Kasuya, 2002). However, these illegal catches were never on the same scale as those of the U.S.S.R.

[2]Fred Berzin's memoir (Berzin, 2008) devotes an entire section to Solyanik, with details of his rise to power, abuses, and eventual downfall.

Figure 5.—Solyanik and his wife Svetlana (Sveta) shopping during a port call in Sydney, Australia. Photo by Yuri Mikhalev.

Figure 6.—Yuri Mikhalev (right) and Svetlana Solyanik in Sydney; the man in the middle is unknown. Photo by Yuri Mikhalev.

Southern Ocean and decimated populations of whales. It was Solyanik who was responsible for the huge catches of humpback whales—25,000 in just two seasons—which precipitated the crash of the populations concerned and forced the closure of shore whaling stations in Australia and New Zealand in the early 1960's (Clapham et al., 2009).

It was actually Solyanik himself who first hired Mikhalev. He asked the young biologist if he had ever seen a whale. No, Yuri replied honestly, he had not. Solyanik sent him to sea anyway, at the minimum salary of 80 rubles a month. Mikhalev recounts the many abuses meted out on processing crews by Solyanik in his interminable quest for more "product." He was notorious for driving the whale processing crews to exhaustion, even when whaling in the oppressive heat of the tropics, and several men died as a result.

Solyanik stopped at nothing to ensure that his production targets were always met and exceeded. In one case, he read of an impending whaling agreement between Japan and the Government of Argentina, and soon after took the *Sovetskaya Ukraina* fleet to the waters of the latter nation. It was the spring of 1962. There he found a large population of southern right whales that was probably recovering well from 19th century whaling, and killed every animal he could find. At other times, he intentionally gave false information to other Soviet whaling vessels regarding allegedly good whaling grounds in order to ensure that the highest catches were reserved for his own fleets. When the ships arrived, they found that the area had already been swept clean by Solyanik's catchers.

Nor was Solyanik above blatant nepotism. His son Gennady was appointed to the position of whaling inspector, thus creating a truly absurd situation: a man whose father was the worst plunderer of the world's whales being responsible for making sure that whaling regulations were followed. Solyanik even created an unnecessary but highly paid position aboard the factory fleet for his attractive young wife Svetlana (Fig. 5). Not content with this, Solyanik even had a swimming pool constructed on the flying bridge of *Sovetskaya Ukraina* for his wife to play in, a scene that infuriated the crews toiling below in unbearable tropical heat. Still, says Mikhalev (who knew Svetlana well: Fig. 6), people rarely complained about this or any other flaunting of Solyanik's power, no matter how egregious; everyone was afraid of Solyanik, and they all knew that any trouble-maker would be disciplined and sent home. It is a sad commentary on Soviet domestic life at the time that, as terrible as conditions often were on the fleets, they were better (at least economically) than the alternative at home. The pay was better, the food was unlimited, and occasionally the fleets would put into foreign ports where—under careful supervision—the men could go ashore for a few hours to taste another way of life, and to buy large quantities of much-

coveted foreign goods to take back to the U.S.S.R.

Solyanik's downfall began with the publication of a long and highly critical article in the prominent Soviet newspaper *Komsomolskaya Pravda* (Sakhnin, 1965).[3] The article detailed his many abuses of people and the system; and, while Solyanik had very powerful friends, even they could not ignore such a public display of his transgressions. After much infighting and political maneuvering (during which the career of the article's author was effectively ruined), Solyanik was relieved of his elevated position in the whaling industry, stripped of his many Communist Party privileges, and exiled to a lowly position in command of a fishing vessel. His last years were spent in bitterness and paranoia.

It is not entirely true that no one suspected what the Soviets were up to during all those years. For one thing, they themselves provided some clues. For example, the end of the 1950's saw a strange paradox emerging: at a time when all the talk among whalers was of declining populations and of scaling back, the Soviets actually began adding factory ships to their Antarctic fleet. For years, the Soviets also successfully blocked a scheme to place independent observers on whaling ships, an effort that is easy to interpret today.

And occasionally they made mistakes. Two notable errors involved what were known as "Discovery" tags. These were uniquely numbered stainless steel cylinders fired from a shotgun into a whale to "mark" it (and named after the Discovery Committee, a British scientific body which instituted the tagging program). The idea was that some of the marked animals would subsequently be killed, anywhere from the next day to many years later. When a tag was recovered during the butchering process, the biologists could look at its number, consult the records, and discover where the whale had originally been marked. Since they also knew where it had been killed, they would thus learn something about the animal's movements. The recovery of many such tags could potentially provide valuable information about the structure and range of a population.

In 1962, the Soviets reported to the International Whaling Commission that they had recovered a number of Discovery tags in the previous Antarctic season. Among them were tag numbers 15898 and 21815, described as having come from a sperm whale and a fin whale, respectively—both legal species at the time. Commission records, however, showed unequivocally that both tags had been fired into humpback whales. Some people assumed that these mistakes represented simple transcription errors. An Australian biologist named Graeme Chittleborough took a rather less charitable view.

Chittleborough had worked for many years with the Australian whaling industry and was then the foremost authority on humpback whale biology. In 1965, he published a scientific paper summarizing extensive studies of two of the major humpback whale populations in the Southern Hemisphere (Chittleborough, 1965). Using his data to estimate mortality rates, Chittleborough observed that known catches of humpbacks were insufficient to account for the very high rates suggested by his calculations. After considering various possibilities, he concluded that the only reasonable explanation was that someone was taking large numbers of humpbacks illegally. Although he pointedly did not mention the country involved, Chittleborough cited the two Soviet Discovery tag "errors" as evidence that humpbacks were being taken and not reported.

Surprisingly, no one at the International Whaling Commission pursued Chittleborough's accusations. When the truth was finally revealed, even Graeme Chittleborough was staggered by the scale of the illegal catches on humpbacks, which had been hit more heavily than any other species. Over the years, the Soviets had reported taking 2,710 humpback whales in the waters of the Southern Hemisphere. The real total was more than 48,000.

Twenty-eight years after publication of Chittleborough's paper, in December 1993, Alexey Yablokov stood before a large group of marine mammal biologists at a conference in Galveston, Texas. Addressing the meeting's concluding banquet, he stunned his audience by revealing that the Soviets had engaged in massive illegal whaling for three decades. Yablokov, a respected biologist with a long history of research on whales, was then the Science Advisor to Russian President Boris Yeltsin. His speech was made possible only by the dissolution of the Soviet Union 4 years before. It also arose as the end result of a chance conversation.

In 1992, South African biologist Peter Best had bemoaned to a colleague that he was unable to publish a paper on southern right whale pregnancy because he had too small a sample size of fetuses from which to work. Right whales had been extensively hunted in previous centuries, and by 1900 were already considered comparatively rare in much of their historic range. Because the species had not been legally hunted since it was protected in 1935, biologists working on right whales had to rely on a small number of old whaling records, together with a handful of stranded specimens.

The colleague, Robert Brownell of NOAA's National Marine Fisheries Service, mentioned Best's problem to Yablokov one day. Yablokov's response took him completely by surprise. "Alexey told me that he could give Peter some data on right whale fetuses," says Brownell. "When I asked how many, the answer was several hundred." Any biologist familiar with whaling regulations would have been staggered by this number. For a species that had theoretically been protected for six decades, and hunted very little at all this century, the existence of data from several hundred pregnant females was almost inconceivable. As it turned out, more than 3,000 southern right whales had been killed, most by the whaling fleets under the command of Alexei Solyanik.

Thus emerged the truth about Soviet whaling. Recognizing the critical importance of setting the record straight, Brownell immediately began working with Yablokov to identify sources for

[3]Fred Berzin's memoir (Berzin, 2008: 30–35) contains the entire newspaper article.

the true catch data. Although Yablokov was the one to finally break the silence (Yablokov, 1994), most of the details were furnished by other former Soviet whale biologists. Dimitri Tormosov, Fred Berzin, Vyacheslav Zemsky, and Yuri Mikhalev—a group Brownell jokingly refers to as the Gang of Four—had all witnessed the illegal catches firsthand from the decks of factory ships. Encouraged by Yablokov, they worked in various parts of the now-fractured Soviet empire to unearth the true catch data.

Berzin, the former head of the marine mammal laboratory in Vladivostok, would later write a grim but fascinating memoir that provides extensive details of the Soviet whaling campaign. He died in 1996, but the memoir was recently translated and published in the *Marine Fisheries Review* (Berzin, 2008).

Ironically, the Soviet obsession with keeping accurate records of their catches is today helping biologists to better understand—and perhaps ultimately to better assist—the populations that were decimated during this reign of terror. Information from legal catches is highly biased because of the prohibitions on taking certain species, or ages, or sizes of whale. Thus the data sets are often incomplete, and in some cases are of dubious accuracy. If a catcher took an animal that was below the legal minimum size limit, there was a powerful incentive to "add" a few feet to its true length and thus avoid costly fines. Because of the secret nature of Soviet operations and the fact that they killed everything they found, the resulting data have no such problems. Consequently, they can be used to address many questions that the legal records cannot.

Today, almost all of the Southern Hemisphere catch records have been corrected and published (Yablokov et al., 1998; Clapham and Baker, 2002). In addition, work is underway to obtain and analyze information on takes in the Northern Hemisphere. Although records are far more fragmentary, it is clear that the Soviets were far from idle north of the equator. Sperm whales in particular suffered greatly at the hands of Soviet factory fleets, with more than 200,000 estimated to have been killed; of these, more than 100,000 may have been taken illegally. In all, Soviet illegal catches worldwide probably total well over 200,000 animals, and include several protected species. Almost half the Southern Hemisphere total were of humpback whales; but blue whales, sperm whales, sei whales, Bryde's whales, and right whales were all killed in large numbers. Everything that crossed the bow of a catcher boat was taken: any species, and any size, from young calves to the oldest animals. In keeping with the spirit of the best communist philosophy, the Soviets did not discriminate.

During the 20th century, the other whaling nations together killed more than two million whales in the Southern Hemisphere alone (Clapham and Baker, 2002). More than half of this total was made up of catches of the two largest species: 350,000 blue whales and a staggering three quarters of a million fin whales were slaughtered for meat, oil, margarine, pharmaceuticals, and a host of other commercial products. So were 160,000 humpbacks, 380,000 sperm whales, 180,000 sei whales, and around 160,000 others. Add to this the innumerable whales killed in the Northern Hemisphere and you have a slaughter which, in terms of sheer biomass, is greater than anything in the history of human hunting.

Against this background of widespread carnage, one might reasonably ask whether the 100,000 animals caught illegally in the Southern Hemisphere by the Soviet Union, representing just 5% of the region's total catch, made much of a difference to the populations concerned. A similar question could be posed with regard to the North Pacific, where unreported catch totals (especially for sperm whales) may have been even larger. The answer, in at least some cases, is almost certainly yes.

For one thing, the bulk of the Soviet catches were made at a time when the populations of several species were already in serious decline from the excesses of legal whaling. In particular, humpback, blue, and southern right whales suffered the double blow of huge regular catches followed by extensive unreported Soviet takes. In the North Pacific, sperm whales were so devastated by Soviet whaling, with reproductive females killed en masse, that one Soviet scientist noted that they had "left a desert in their wake" (Berzin, 2008). At the very least, then, the illegal catches served to seriously inhibit the recovery of these populations.

Encouragingly, both humpback and southern right whales seem to be making a comeback in most places where they are being studied. In some areas, however, such as the waters off the island of South Georgia and around New Zealand, some previously abundant species are today represented by remnant populations (Clapham et al., 1999). Whether they will eventually recover is, at this point, anyone's guess.

One population that may not is that of the right whale in the eastern North Pacific. Right whales are indisputably among the rarest of all the world's whales. Slow and easy to catch, and yielding a huge quantity of high quality oil and baleen, right whales were so named by early whalers simply because they were the "right" whale to kill. They were hunted in the North Atlantic as early as the 11th century, and just as intensively in the North Pacific starting in the 1830's. By 1900, northern right whales were already so rare throughout their range that they had ceased to be a principal target for whalers anywhere. Like their Southern Hemisphere counterparts, they were completely protected from hunting by international agreement in 1935.

In 2001, a group of scientists including one of us (PJC) undertook a review of all records of right whales in the North Pacific this century (Brownell et al., 2001). The exercise revealed an alarming trend. Although right whales have never been numerous in the eastern part of this ocean during the 20th century, reasonable numbers were being sighted for many years. Whale catchers searching for other species reported seeing modest concentrations of right whales each year, particularly in the Bering Sea, the Aleutian Islands, and the Gulf of Alaska. Around 1964, however, a dramatic drop in sightings is evident.

Despite the fact that search effort actually increased, there were barely 60 observations of right whales in the entire eastern North Pacific from 1964 to 2001, when our paper was published.

In light of what we now know, it was not hard to guess the nature of the calamity that overtook the right whale population in the early sixties. Nor was it difficult to interpret a large number of right whale "sightings" reported by Soviet whalers around this period. There, as elsewhere, the whalers went beyond mere observation of these animals and killed as many as they could, with disastrous consequences. Thanks to Nikolai Doroshenko, another former Soviet biologist, we now know that the U.S.S.R. killed 372 right whales, most in a 3-year period beginning in 1963 (Doroshenko, 2000). These animals, which were taken in the Bering Sea and Gulf of Alaska, probably comprised the bulk of the existing population (Ivashchenko et al., 2007).

In 1835, an American whaling ship named *Ganges* became the first of her kind to arrive in the Pacific Northwest, and there the awestruck captain reported seeing "a million right whales" (Webb, 1988). While this was clearly a gross exaggeration, the statement is testament to the abundance of this species in the North Pacific prior to the first whaling catches. Less than two centuries later, the species is now so rarely sighted in the region that single observations have been publishable in scientific journals. We cannot be sure, but it is entirely possible that when the few remaining right whales in the eastern North Pacific live out their lives and die, the species will be gone forever from these waters. Although Soviet whalers were certainly not responsible for the bulk of the catches on this population, they may well possess the dubious distinction of having effectively finished it off.

Sovetskaya Ukraina made her maiden voyage in 1959. Twenty-eight years and some 130,000 whales later, the old factory ship ended her life as a whaler and was converted to other uses. Finally, in 1995 she was sold for scrap.

The demise of *Sovetskaya Ukraina* was attended by rather more sentimentality than had been accorded the whales. Before leaving Odessa, the vessel was given a ceremonial farewell, and those who had worked aboard her were offered souvenirs ranging from clocks to navigator's rules to cartridge cases from the shells used to fire harpoons.

Figure 7.—*Sovetskaya Ukraina* at Aliaga, Turkey, prior to breaking up, August 1995. Photo by Selim San.

Then, the ceremony over, *Sovetskaya Ukraina* was towed to a shipyard in Turkey (Fig. 7). There, in a final irony, the vessel that had presided over the destruction of so many whales met a fate oddly like that of her longtime quarry. Under the blue light of acetylene torches, the decks that had once run with the blood of giants were themselves systematically carved up and disposed of.

If there is a lesson to be learned from this particularly shameful chapter of whaling history, it is that international agreements are essentially worthless unless accompanied by rigid provisions for inspection and enforcement. Today, there are insistent calls by Japan and some other nations for a resumption of commercial whaling, and this topic is hotly debated within the IWC (Clapham et al., 2007). One of the major issues revolves around the IWC's "Revised Management Scheme," the set of procedures and controls that would have to be established should the current moratorium on whaling be lifted.

Within this debate, there are still many voices in the international community arguing that self-regulation is entirely adequate in environmental matters. Of the many images that one could summon to counter such assurances, few are as powerful as that of Soviet whaling fleets, and 200,000 dead whales.

Acknowledgments

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Errata

Berzin, Alfred A. 2008. The Truth about Soviet Whaling. *Marine Fisheries Review* 70(2):4-59.

On page 9, footnote 21 should read:

[21]Translator's note: Zenkovich, ВОКРУГ СВЕТА ЗА КИТАМИ, 1936, Leningrad, Molodaya gvardiya Leningradskoe otdelenie.

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